IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

RE-SUBMISSION OF APPEAL BRIEF

APPELLANTS:	Hetzer et al.	CONFIRMATION NO. 6272
SERIAL NO.:	09/911.811	GROUP ART UNIT: 2853
FILED:	July 24, 2001	EXAMINER: Leonard s. Liang
TITLE:	"ARRANGEMENT AND METHOD FOR DATA FOLLOW UP FOR WARMUP CYCLES OF INK JET PRINT HEADS"	

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P.O. Box 1450
Alexandria, Virginia 22313-1450

S I R:

In a Notification of Non-Compliant Appeal Brief mailed January 10, 2008, it was stated that the Appendix that was entitled "Related Appeals and Interferences Appendix" should be called "Related Proceedings Appendix" in order to give proper notice to not only appeals and interferences, but also Court decisions. Appellants have complied with this request, but submit this is a meaningless and trivial request that has served no purpose and has only delayed this proceeding, and has created a significant separation in time between the time that the present appeal will be transmitted to the Board of Patent Appeals and Interferences, and the time that the Board of Patent Appeals and Interferences will review the related appeal. Obviously, if there has been no decision by the Board of Patent Appeals and Interferences in connection with the related appeal, there could not have been any Court decision.

The revised statement in the re-submitted Appeal Brief, therefore, adds no further information for use by the Examiner or by the Board of Patent Appeals and Interferences.

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE BOARD OF PATENT APPEALS AND INTERFERENCES

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APPELLANTS' REVISED MAIN BRIEF ON APPEAL

S I R:

In accordance with the provisions of 37 C.F.R. §41.37, Appellants herewith submit their main brief in support of the appeal of the above-referenced application.

REAL PARTY IN INTEREST:

The real party in interest is the assignee of the present application, Francotyp-Postalia GmbH, a German corporation, which is the successor to Francotyp-Postalia AG & CO. KG, identified as the Assignee in the records of the United States Patent and Trademark Office.

RELATED APPEALS AND INTERFERENCES:

The present Appeal is related to the co-pending Appeal in Serial No. 10/842,694, filed on May 10, 2004 as a divisional application of the present application, claiming a method comparable to the apparatus which is the subject of the claims on appeal in the present application. The Notice of Appeal for Serial No. 10/842,694 was filed simultaneously with the Notice of Appeal for the present application, and the Appeal Brief also is being filed simultaneously herewith. An

Appeal No. has not yet been assigned to Serial No. 10/842,694. No decision has rendered by the Board of Patent Appeals and Interferences in connection with the Appeal of Serial No. 10/842,694.

STATUS OF CLAIMS:

The present application was filed with claims 1-23 as original claims, which included claims 1-12 that are the subject of the present Appeal, and claims 13-23 directed to a corresponding method. In response to a restriction requirement, claims 13-23 were cancelled from the present application and made the subject of the aforementioned divisional application Serial No. 10/842,694.

A further claim 24 was added during previous prosecution, but has now been cancelled. Claims 1-12, which are the subject of the present Appeal, therefore constitute all pending claims of the application.

STATUS OF AMENDMENTS:

No Amendment has been filed following the final rejection.

SUMMARY OF CLAIMED SUBJECT MATTER:

The subject matter on appeal is explained using the example of claim 1 (which is the only independent claim on appeal), with exemplary citations to the drawings and specification.

1. An arrangement for determining data for a warm-up cycle of an ink jet printhead, said arrangement comprising:

an ink cartridge (21, 22 in Figs 1 and 2) having an ink jet printhead and a drive unit (unit 211, Figs 1 and 4) connected to the ink jet printhead for heating, measuring a temperature of, and driving the ink jet printhead (p.9, l.22 - p.10, l.4);

a control unit (unit 141 in Fig. 4) connected to the drive unit (211) for controlling the drive unit (p.12, l.7-12);

a memory (memory 210 in Fig. 4.) accessible by said control unit having a first memory area in which warmup data are stored in re-writable fashion, and a second memory area in which data representing at least two predetermined conditions are stored (p.13, l.19-23), said at least two predetermined conditions being selected from the group consisting of temperature-related conditions, history-related conditions and user-related conditions (p.6, l.11-19);

a sensor (sensor 2119 in Fig. 4) connected to said drive unit for measurement of ambient temperature (p.17, l.16-18); and

said control unit being programmed to implement at least one measurement of said ambient temperature with said sensor, and to determine warm-up data for a fast start, executed in less than 30 seconds, for a current warm-up cycle dependent upon said ambient temperature and dependent on said at least two predetermined conditions (p.19, l.15 - p.20, l.12).

GROUNDS OF REJECTION TO BE REVIEWED ON APPEAL:

The following rejections are presented for review in the present Appeal:

Whether the subject matter of claims 1, 10 and 11 would have been obvious to a person of ordinary skill in the field of design and operation of ink jet printers under the provisions of 35 U.S.C. §103(a), based on the teachings of United States

Patent No. 4,791,435 (Smith et al.) in view of the teachings of United States Patent No. 5,107,276 (Kneezel et al.);

Whether the subject matter of claims 2-4, 6-8 and 12 would have been obvious to a person of ordinary skill in the field of design and operation of ink jet printers under the provisions of 35 U.S.C. §103(a), based on the teachings of Smith et al. in view of Kneezel et al., further in view of the teachings of United States Patent No. 5,812,156 (Bullock et al.); and

Whether the subject matter of claims 5 and 9 would have been obvious to a person of ordinary skill in the field of design and operation of ink jet printers under the provisions of 35 U.S.C. §103(a), based on the teachings of Smith et al. in view of Kneezel et al. and Bullock et al., further in view of the teachings of United States Patent No. 5,513,563 (Berson).

ARGUMENT:

Rejection of Claims 1, 10 and 11 Under 35 U.S.C. §103(a) Over Smith et al. and Kneezel et al.

The arrangement claimed in claim 1 on appeal requires a memory that is accessible by the control unit having a first memory area in which warm-up data are stored in re-writable fashion, and a second memory area containing data representing at least two predetermined conditions, the two predetermined conditions being selected from the group consisting of temperature-related conditions, history-related conditions and user-related conditions. The arrangement also includes an ambient temperature sensor. The control unit implements at least one measurement of the ambient temperature with the aforementioned sensor, and then determines warm-up data for a fast start dependent on the ambient temperature

and dependent on the at least two predetermined conditions. This means that the control unit formulates the warm-up data for the fast start dependent not only on the ambient temperature, but also dependent on at least two of temperature-related conditions, history-related conditions and user-related conditions.

Appellants respectfully submit the Smith et al reference is extremely general and uninformative as to how, or even if, information contained in the read-only memory section 2b of the microprocessor 2 is used by the pulse generator 24a to generate pulses that are supplied to the print head 21 for any purpose, much less during a warm-up cycle. In Figure 2A of the Smith et al reference, all of the signal lines proceeding from the data processing section 2a to the read-only memory section 2b proceed in one and only one direction, namely *from* the data processing section 2a *to* the read-only memory section 2b. Therefore, it is clear that the data processing section 2a of the microprocessor 2 does not and cannot make use of any of the information stored in the read-only memory section 2b. Although the data processing section 2a includes an input T from a temperature sensor TS located at the printhead 21 (i.e., *not* an ambient temperature sensor) this appears to be only for the purpose of feeding the temperature information through the data processing section 2a, and through the read-only memory section 2b, to the pulse generator 24a. The outputs a through g of the read-only memory section 2b are merely shown in Figure 2B as proceeding into the pulse generator 24a. The only designated or described function that takes place in the pulse generator 24a is to supply warm-up pulses from output b in Figure 2a to a section of the pulse generator 24a in Figure 2B designated "pulse width control." There is no indication whatsoever in the Smith et al reference that anything other than the sensed temperature is used to determine

or set the pulse width of the warm-up pulses in the pulse generator 24a. There is not even any indication of how the other information from the read-only memory section 2b is used at all by the pulse generator 24a, but presumably that information is used for normal text printing, since the only disclosed relationship between warm-up pulses and the pulse generator 24a in the Smith et al reference is the aforementioned "pulse width control."

Therefore, even in the context of the non-ambient temperature sensed in the Smith et al reference, there is no disclosure or suggestion in that reference that anything other than this sensed temperature is used to set the pulse width of the warm-up pulses. This is in contrast to the subject matter of claim 1 wherein the ambient temperature is sensed and this ambient temperature is then used, together with at least two other predetermined conditions, to determine the warm-up data with in the control unit that are used for a fast start.

The Examiner relied on the Kneezel et al reference as disclosing a sensor that is able to sense ambient temperature. Appellants agree that the Kneezel et al reference discloses such an ambient temperature sensor, but disagree with the Examiner's conclusion that there is a control unit in the Kneezel et al reference that is programmed to implement a measurement of the ambient temperature using that sensor, and to determine warm-up data for a fast start dependent on the ambient temperature and dependent on at least two predetermined conditions.

As can be seen in Figure 5A of the Kneezel et al reference, the ambient temperature sensor 55 supplies an output to a subthreshold pulse width controller 56. Optionally, the ambient temperature sensor 55 also supplies an output to a look-up table 57, which then supplies an output to the sub-threshold pulse width controller

56. The pulse width is then determined exclusively within the pulse width controller 56, and the already-determined pulse width is then supplied as an output from the subthreshold pulse width controller 56 to the logic controller 58. Therefore, in the Kneezel et al reference, the logic controller 58 merely receives an already-determined pulse width from the subthreshold pulse width controller 56. The logic controller 58 in the Kneezel et al reference, therefore, does not and cannot determine the pulse width dependent on other factors, since the pulse width has already been determined externally of the logic controller 58 and merely supplied as an input to the logic controller 58.

Therefore, even if the Smith et al reference were modified in accordance with the teachings of Kneezel et al, to use an ambient temperature sensor in place of, or in addition to, the temperature sensor TS disclosed in the Smith et al reference, there still is no teaching or suggestion in either of those references to do anything except use the ambient temperature, by itself, to set a pulse width of pulses that may (possibly) be used in a warm-up cycle. There is no teaching in either the Smith et al or Kneezel et al references to make use of the ambient temperature to determine warm-up data in combination with (dependent on) at least two predetermined conditions from the aforementioned list of predetermined conditions, as set forth in claim 1 of the present application.

Appellants respectfully submit it is only with the benefit of hindsight after reading the present disclosure that the Examiner has assumed that either the Smith et al reference or the Kneezel et al reference makes use of some sort of combination of the ambient temperature and at least two predetermined conditions for determining warm-up data for a fast start.

These arguments were made during prosecution before the Examiner, and in the Final Rejection the Examiner responded to those arguments. In that response, the Examiner stated that Appellants' argument rests on the contention that

> "The Smith et al. reference is extremely general and uninformative as to how, or even if, information contained in the read only memory section 2b of the microprocessor 2 is used by the pulse generator 24a to generate pulses that are supplied to the printhead 21 for any purpose, much less during a warm-up cycle. ...There is no indication whatsoever in the Smith et al. reference that anything other than the sensed temperature is used to determine or set the pulse width of the warm-up pulses in the pulse generator 24a. There is not even any indication of how the other information from the read only memory section 2b is used at all by the pulse generator 24a... ."

In response, the Examiner cited column 4, lines 52-63 of the Smith et al. reference, which states:

> In the microprocessor, the indication of printhead temperature is employed in a decision making process to determine the temperature condition of the nozzles, i.e., whether the nozzles are cold or whether the nozzles are overheating and is **used with processor based information as to the location of the nozzles on the substrate, the color of the ink in a particular printhead and the use profile of that printhead, for providing input to the logic array circuit 24 for producing print pulses for firing the nozzles of that particular printhead, to maintain uniformity in the ink drops which are fired.** (Emphasis added by Examiner)

The Examiner stated that although the figures themselves in the Smith et al. reference may seem general and uninformative, when coupled with the specification of Smith et al., it is quite clear that the Smith et al. reference discloses firing pulses not only based on the sensed temperature, but also based on some of the parameters in reference 2b, such as ink color and use profile. The Examiner also cited column 2, lines 8-13 of the Smith et al. reference in support of this position. The Examiner also noted that Figure 1 of the Smith et al. reference shows bus lines proceeding to and from the logic array and the microprocessor 2, but noted that only

one bus line is labeled with a reference number (reference no. 23). The Examiner stated it is possible that some of the other figures in the Smith et al. reference were meant only as illustrations of one such aspect of the invention.

In response, Appellants submit that the citations by the Examiner support Appellants' arguments, rather than refuting them. The passage cited by the Examiner, although making mention of the factors emphasized by the Examiner, still provides no guidance whatsoever to a person of ordinary skill in the art as to how those factors should be used. The passage by the Examiner simply provides a statement of a number of factors, together with a statement of an ultimate goal ("to maintain uniformity in the ink drops which are fired"), but neither this passage, nor any other passage in the Smith et al. reference, provides any information as to how those factors can or should be used to accomplish that goal. Clearly, there is no teaching in the Smith et al. reference that rises to the level of detail of the subject matter of claim 1 on appeal.

The provisions of 35 U.S.C. §103(a) require that the Smith et al. reference be interpreted in the manner of a person of ordinary skill who is seeking to solve a particular problem in the relevant technology, and who has not had the benefit of reading the disclosure of the present application. Appellants respectfully submit that the Examiner's belief that the Smith et al. disclosure, in particular the cited passages thereof, provides any specific information that would guide a person of ordinary skill in the field of design and operation of ink jet printers to arrive at the subject matter of claim 1 of the present application, results only from the Examiner having had the benefit of first reading Appellants' disclosure. Appellants respectfully submit that an

objective reading of the Smith et al. reference supports the position of the Appellants, rather than the position of the Examiner.

The Federal Circuit stated in *In re Lee* 227 F.3d 1338, 61 U.S.P.Q. 2d 1430 (Fed. Cir. 2002):

> "The factual inquiry whether to combine references must be thorough and searching. ...It must be based on objective evidence of record. This precedent has been reinforced in myriad decisions, and cannot be dispensed with."

Similarly, quoting *C.R. Bard, Inc. v. M3 Systems, Inc.,* 157 F.3d 1340, 1352, 48 U.S.P.Q. 2d 1225, 1232 (Fed. Cir. 1998), the Federal Circuit in *Brown & Williamson Tobacco Court v. Philip Morris, Inc.,* 229 F.3d 1120, 1124-1125, 56 U.S.P.Q. 2d 1456, 1459 (Fed. Cir. 2000) stated:

> [A] showing of a suggestion, teaching or motivation to combine the prior art references is an 'essential component of an obviousness holding'.

In *In re Dembiczak,* 175 F.3d 994,999, 50 U.S.P.Q. 2d 1614, 1617 (Fed. Cir. 1999) the Federal Circuit stated:

> Our case law makes clear that the best defense against the subtle but powerful attraction of a hindsight-based obviousness analysis is rigorous application of the requirement for a showing of the teaching or motivation to combine prior art references.

Consistently, in *In re Rouffet,* 149 F.3d 1350, 1359, 47 U.S.P.Q. 2d 1453, 1459 (Fed. Cir. 1998), the Federal Circuit stated:

> [E]ven when the level of skill in the art is high, the Board must identify specifically the principle, known to one of ordinary skill in the art, that suggests the claimed combination. In other words, the Board must explain the reasons one of ordinary skill in the art would have been motivated to select the references and to combine them to render the claimed invention obvious.

In *Winner International Royalty Corp. v. Wang,* 200 F.3d 1340, 1348-1349, 53 U.S.P.Q. 2d 1580, 1586 (Fed. Cir. 2000), the Federal Circuit stated:

> Although a reference need not expressly teach that the disclosure contained therein should be combined with another, ... the showing of combinability, in whatever form, must nevertheless be clear and particular.

Lastly, in *Crown Operations International, Ltd. v. Solutia, Inc.*, 289 F.3d 1367, 1376, 62 U.S.P.Q. 2d 1917 (Fed. Cir. 2002), the Federal Circuit stated:

> There must be a teaching or suggestion within the prior art, within the nature of the problem to be solved, or within the general knowledge of a person of ordinary skill in the field of the invention, to look to particular sources, to select particular elements, and to combine them as combined by the inventor.

In the aforementioned response of the Examiner in the Final Rejection, the Examiner stated that Appellants other arguments depend on the above argument regarding the teachings of Smith et al. Appellants acknowledge that Appellants' position regarding the teaching of Smith et al. is the starting point for all Appellants' other arguments, however, Appellants' argument in support of patentability is the totality of the above discussion, including the necessity of satisfying the rigorous evidentiary standards in order to justify a rejection under 35 U.S.C. §103(a). Appellants respectfully submit that the Examiner's rejection of claim 1 based on the teachings of Smith et al. and Kneezel et al. does not satisfy those rigorous evidentiary standards. In this context, the fact that the Smith et al. disclosure is so general is certainly relevant, but equally relevant is Appellants' disagreement with the Examiner's conclusions regarding the teachings of Kneezel et al. and, most importantly, Appellants' argument is based on a lack of any guidance or motivation or inducement in either of those references that satisfies the degree of specificity required by the above-cited Federal Circuit decisions in order to properly substantiate a rejection under 35 U.S.C. §103(a).

Claims 10 and 11 add further structure to the non-obvious combination of claim 1, and therefore neither of those claims would have been obvious to a person of ordinary skill in the field of design and operation of ink jet printers under the provisions of 35 U.S.C. §103(a), based on the teachings of Smith et al. and Kneezel et al., for the same reasons discussed above in connection with claim 1.

Rejection of Claims 2-4, 6-8 and 12 Under 35 U.S.C. §103(a) Based on Smith et al., Kneezel et al. and Bullock et al.

Each of claims 2-4, 6-8 and 12 depends directly or indirectly from claim 1, and therefore each of those claims embodies the subject matter of claim 1 therein. In view of the above discussion regarding the Smith et al./Kneezel et al. combination as applied against claim 1, Appellants respectfully submit that even if the Smith et al./Kneezel et al. combination were further modified in accordance with the teachings of Bullock et al., the subject matter of claims 2-4, 6-8 and 12 still would not result. Even if the Examiner's statements regarding the teachings of Bullock et al. are correct, Appellants respectfully submit the Examiner still has failed to present a properly supported bases for rejecting any claims 2-4, 6-8 and 12 under the provisions of 35 U.S.C. §103(a) based on the teachings of those references.

Rejection of Claims 5 and 9 Under 35 U.S.C. §103(a) Based on Smith et al., Kneezel et al., Bullock et al. and Berson

Each of claims 5 and 9 depends indirectly from claim 1, and therefore each of those claims embodies the subject matter of claim 1 therein. In view of the above discussion regarding the Smith et al./Kneezel et al. combination as applied against claim 1, Appellants respectfully submit that even if the Smith et al./Kneezel et al. combination were further modified in accordance with the teachings of Bullock et al., and Berson the subject matter of claims 5 and 9 still would not result. Even if the

Examiner's statements regarding the teachings of Bullock et al. and Berson are correct, Appellants respectfully submit the Examiner still has failed to present a properly supported bases for rejecting any claims 5 and 9 under the provisions of 35 U.S.C. §103(a) based on the teachings of those references.

CONCLUSION:

For the foregoing reasons, Appellants respectfully submit the Examiner is in error in law and in fact in rejecting claims 1-12 of the present application. Reversal of the those rejections is proper, and the same is respectfully requested.

The previously-filed Appeal Brief was accompanied by payment for the requisite fee in the amount of $500.00, which is applicable to the present Brief as well.

An oral hearing was previously requested, and Appellants reiterate their request for such an oral hearing. The appropriate fee was paid at the time the oral hearing was previously requested.

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CLAIMS APPENDIX

1. An arrangement for determining data for a warm-up cycle of an ink jet printhead, said arrangement comprising:

an ink cartridge having an ink jet printhead and a drive unit connected to the ink jet printhead for heating, measuring a temperature of, and driving the ink jet printhead;

a control unit connected to the drive unit for controlling the drive unit;

a memory accessible by said control unit having a first memory area in which warmup data are stored in re-writable fashion, and a second memory area in which data representing at least two predetermined conditions are stored, said at least two predetermined conditions being selected from the group consisting of temperature-related conditions, history-related conditions and user-related conditions;

a sensor connected to said drive unit for measurement of ambient temperature; and

said control unit being programmed to implement at least one measurement of said ambient temperature with said sensor, and to determine warm-up data for a fast start, executed in less than 30 seconds, for a current warm-up cycle dependent upon said ambient temperature and dependent on said at least two predetermined conditions.

2. An arrangement as claimed in Claim 1, said memory is a first memory, and wherein said arrangement comprises:

a second memory disposed on said ink cartridge, in which identification data uniquely identifying said ink cartridge, and data representing further predetermined conditions, are stored, and wherein said warm-up data stored in said first memory are allocated to said identification data.

3. An arrangement as claimed in Claim 2 wherein said ink cartridge has a serial number uniquely associated therewith, and wherein said identification data includes said serial number.

4. An arrangement as claimed in Claim 2 wherein said ink cartridge has a manufacturer identification number uniquely associated therewith, and wherein said identification data includes said manufacturer identification number.

5. An arrangement as claimed in Claim 2 wherein said ink cartridge has a serial number and a manufacturer identification number uniquely associated therewith, and wherein said control unit comprises a security module for forming a code word by encryption of said serial number and said manufacturer identification number, and wherein said control unit stores said code word in said second memory as at least a portion of said identification data.

6. An arrangement as claimed in Claim 1 wherein said memory is disposed on said ink cartridge and wherein said second memory area additionally contains identification data uniquely identifying said ink cartridge, and data representing further predetermined conditions allocated to said identification data, and wherein said control unit is programmed to interrogate said memory to

determine said warm-up data employing said further predetermined conditions allocated to said identification data.

7. An arrangement as claimed in Claim 6 wherein said ink cartridge has a serial number uniquely associated therewith, and wherein said identification data includes said serial number.

8. An arrangement as claimed in Claim 6 wherein said ink cartridge has a manufacturer identification number uniquely associated therewith, and wherein said identification data includes said manufacturer identification number.

9. An arrangement as claimed in Claim 6 wherein said ink cartridge has a serial number and a manufacturer identification number uniquely associated therewith, and wherein said control unit comprises a security module for forming a code word by encryption of said serial number and said manufacturer identification number, and wherein said control unit stores said code word in said second memory as at least a portion of said identification data.

10. An arrangement as claimed in Claim 1 wherein said drive unit includes a sensor for measuring the temperature of the ink jet printhead, said sensor generating sensor data representing said temperature, and wherein said control unit is programmed to interrogate said sensor data via said drive unit for determining said warm-up data.

11. An arrangement as claimed in Claim 1 comprising:

a user interface connected to said control unit for entering a user request for said fast start;

a communication link, connected to said control unit, to a remotely disposed telepostage data center which, upon receipt of said user request, transmits a parameter for said fast start, including an identification of said user, to said control unit, and wherein said control unit is programmed to store said parameter in said memory and to employ said user related conditions, corresponding to the user identified by said parameter, as one of said at least two conditions for determining said warm-up data for said fast start.

12. An arrangement as claimed in Claim 1 further comprising a date clock module connected to said control unit for generating history-related data as said history-related conditions .

RELATED PROCEEDINGS APPENDIX

No decision by the Board of Patent Appeals and Interferences has been rendered in connection with the related appeal for Serial No. 10/842,694, nor has any Court decision been rendered in connection with that related appeal.

EVIDENCE APPENDIX

Exhibit A: Figs. 1-4 - Filed with the original application on July 24, 2001.

Exhibit B: United States Patent No. 4,791,435 (Smith et al.) - Cited in the Final Rejection dated December 21, 2005.

Exhibit C: United States Patent No. 5,107,276 (Kneezel et al.) - Cited in the Final Rejection dated December 21, 2005.

Exhibit D: United States Patent No. 5,812,156 (Bullock et al.) - Cited in the Final Rejection dated December 21, 2005.

Exhibit E United States Patent No. 5,513,563 (Berson) - Cited in the Final Rejection dated December 21, 2005.

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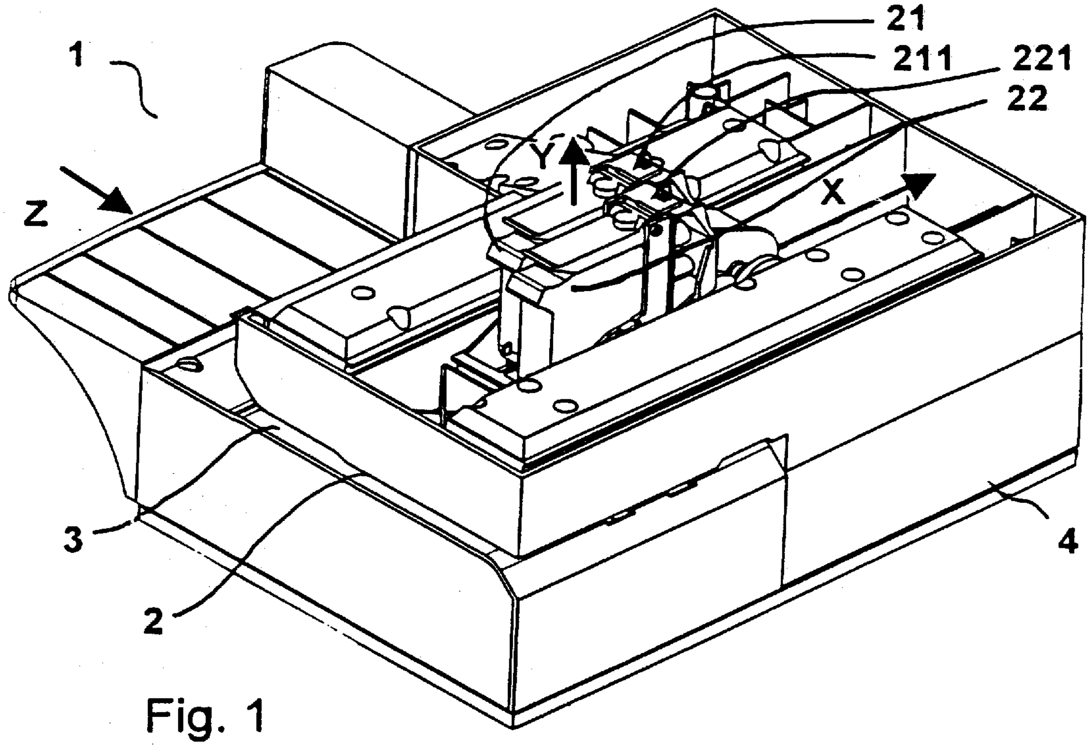
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Fig. 1

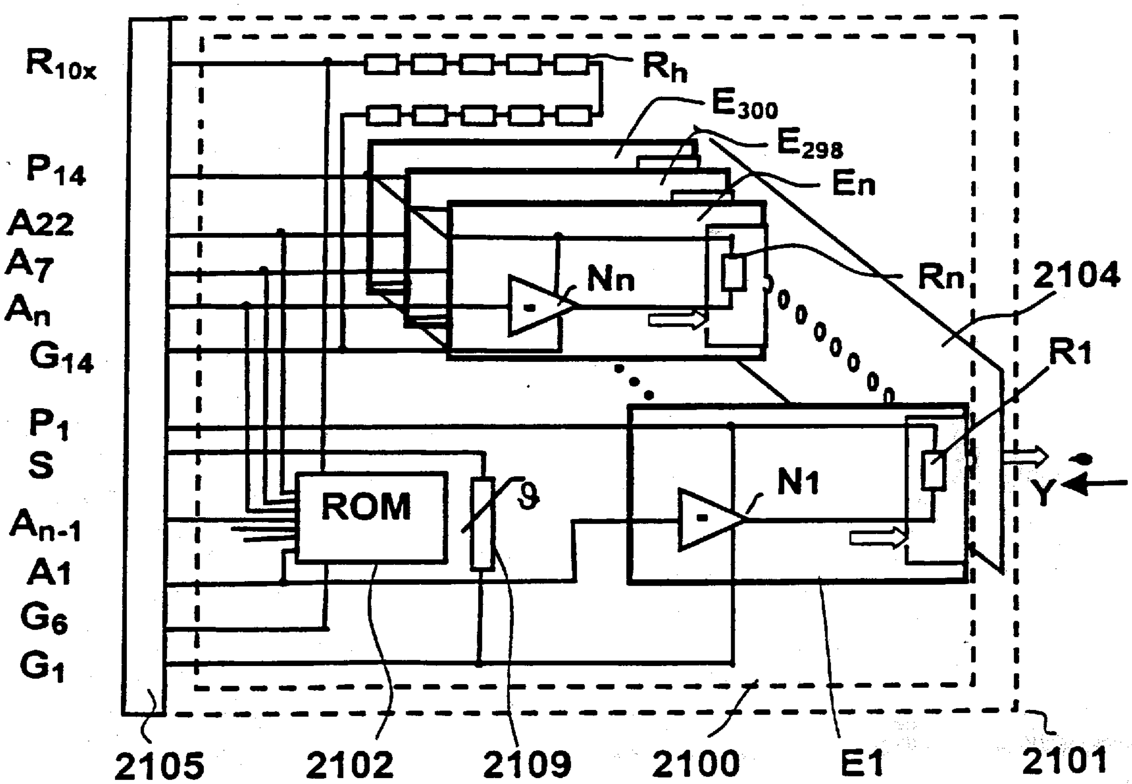
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Fig. 3

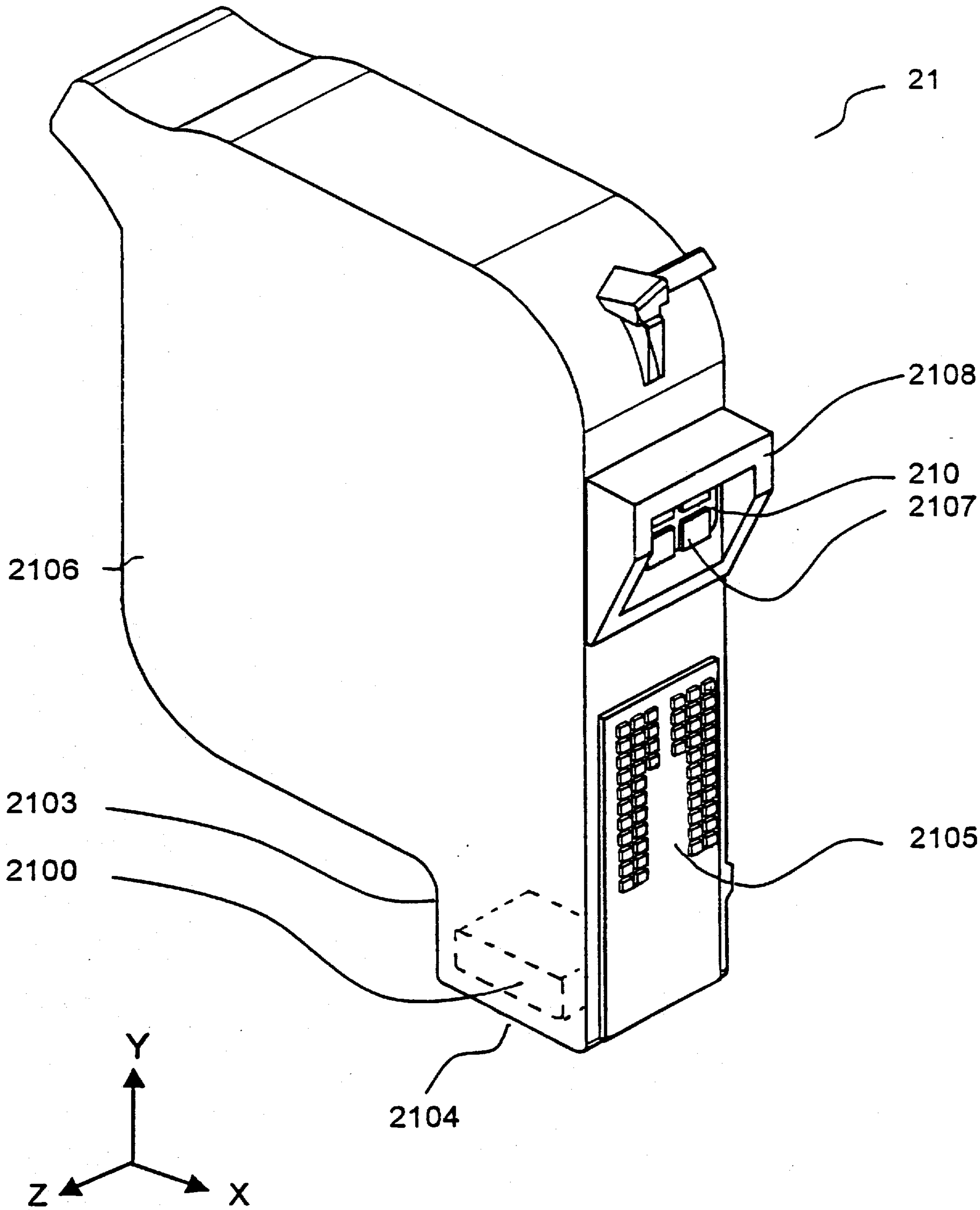
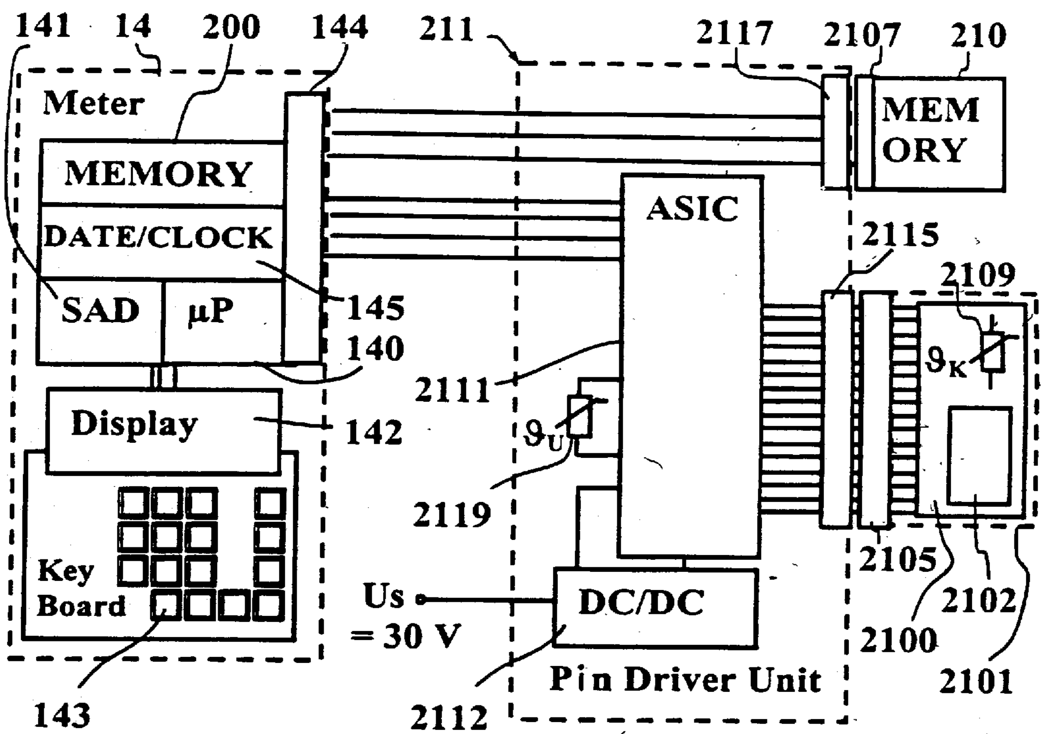


Fig. 2



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211
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Meter
MEMORY
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140
ϑ_K
2111
ϑ_U
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2119
Key Board
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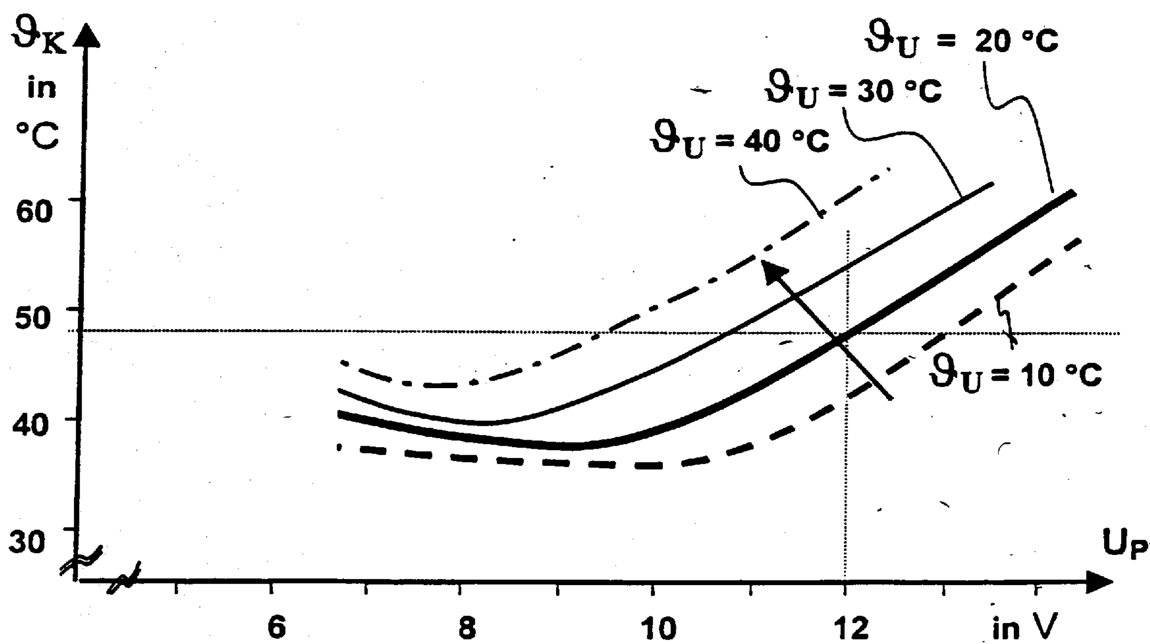
DC/DC
2105
2102
2100
2101
Pin Driver Unit
143
2112

Fig. 4



ϑ_K in °C
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50
40
30
ϑ_U = 20 °C
ϑ_U = 30 °C
ϑ_U = 40 °C
ϑ_U = 10 °C
U_P
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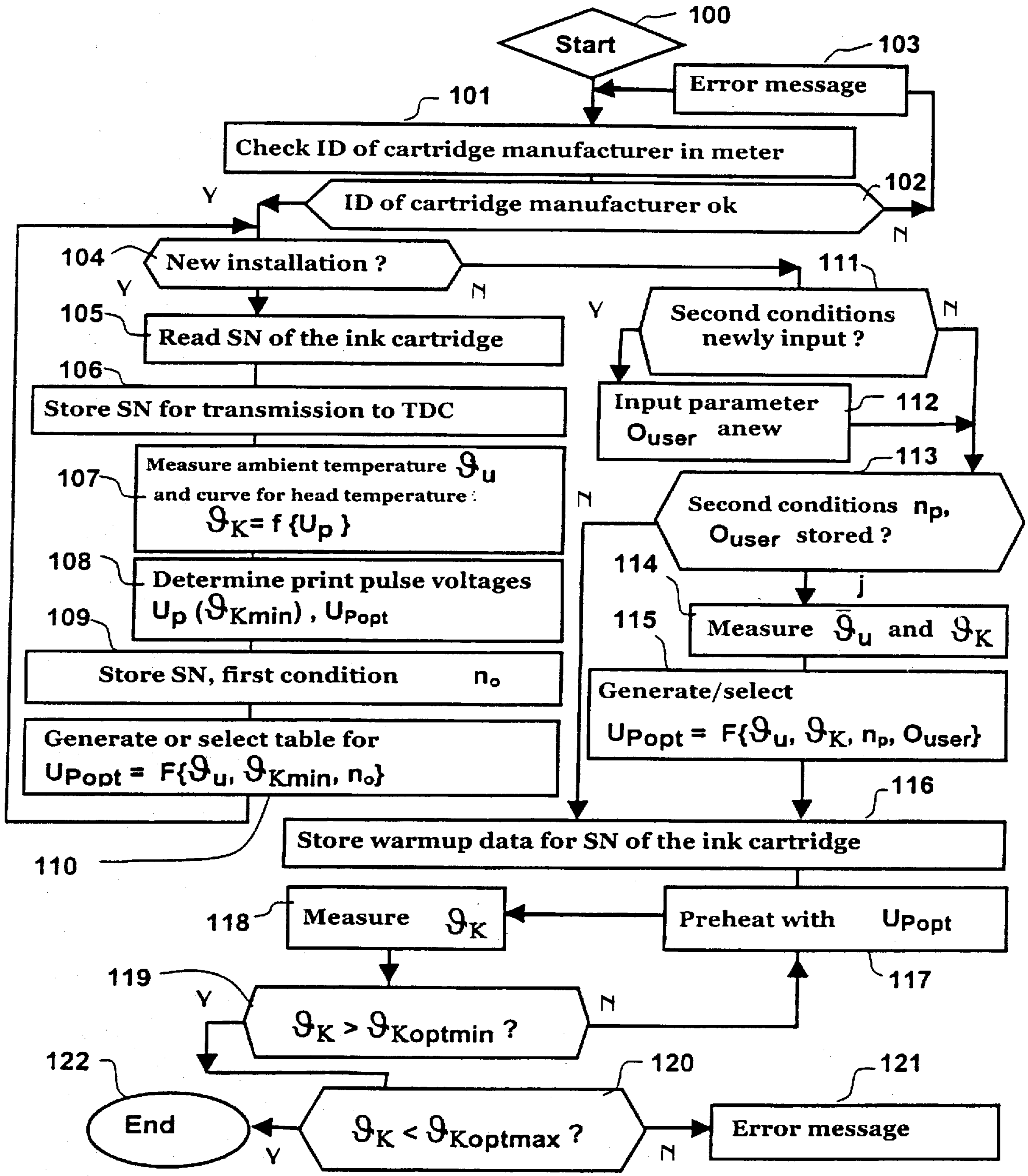
8
10
12
in V

Fig. 5



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101
Check ID of cartridge manufacturer in meter
102
ID of cartridge manufacturer ok
Y
N
104
New installation ?
Y
N
105
Read SN of the ink cartridge
106
Store SN for transmission to TDC
107
Measure ambient temperature ϑ_u
and curve for head temperature :
$\vartheta_K = f\{U_p\}$
108
Determine print pulse voltages
$U_p(\vartheta_{Kmin})$, U_{Popt}
109
Store SN, first condition n_o
Generate or select table for
$U_{Popt} = F\{\vartheta_u, \vartheta_{Kmin}, n_o\}$
110
111
Second conditions newly input ?
Y
N
Input parameter O_{user} anew
112
113
N
Second conditions n_p, O_{user} stored ?
j
114
Measure ϑ_u and ϑ_K
115
Generate/select
$U_{Popt} = F\{\vartheta_u, \vartheta_K, n_p, O_{user}\}$
116
Store warmup data for SN of the ink cartridge
118
Measure ϑ_K
Preheat with U_{Popt}
117
119
Y
$\vartheta_K > \vartheta_{Koptmin}$?
N
122
120
121
End
$\vartheta_K < \vartheta_{Koptmax}$?
Y
N
Error message

Fig. 6

United States Patent [19]

Smith et al.

[11] Patent Number: 4,791,435

[45] Date of Patent: Dec. 13, 1988

[54] THERMAL INKJET PRINTHEAD TEMPERATURE CONTROL

[75] Inventors: James C. Smith; Hatem E. Mostafa; William J. Walsh, all of San Diego, Calif.

[73] Assignee: Hewlett-Packard Company, Palo Alto, Calif.

[21] Appl. No.: 77,552

[22] Filed: Jul. 23, 1987

[51] Int. Cl.[4] G01D 15/24

[52] U.S. Cl. .... 346/140 R; 346/139 R; 400/54

[58] Field of Search .... 346/140, 75, 76 PH, 346/139 R; 400/54

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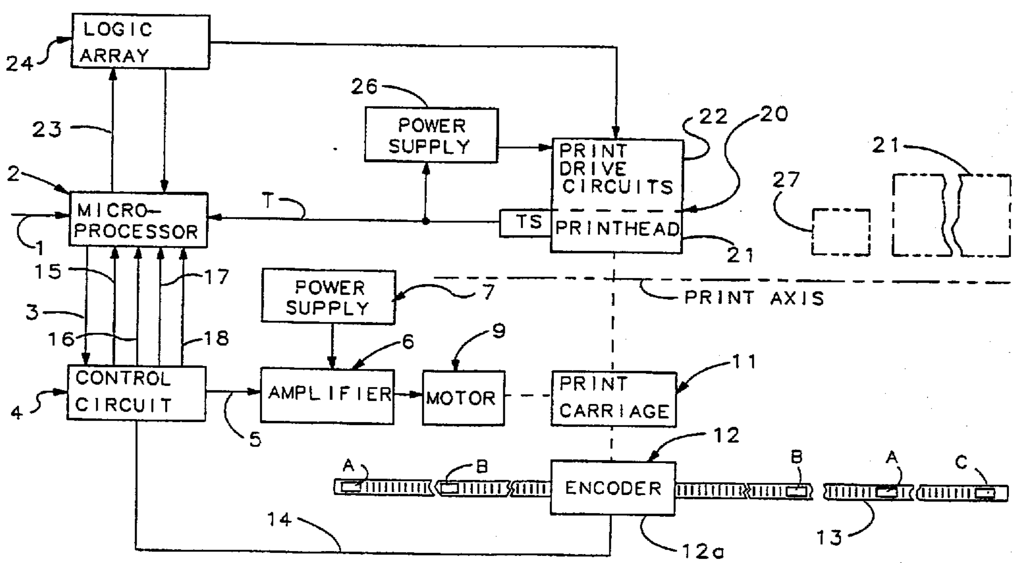
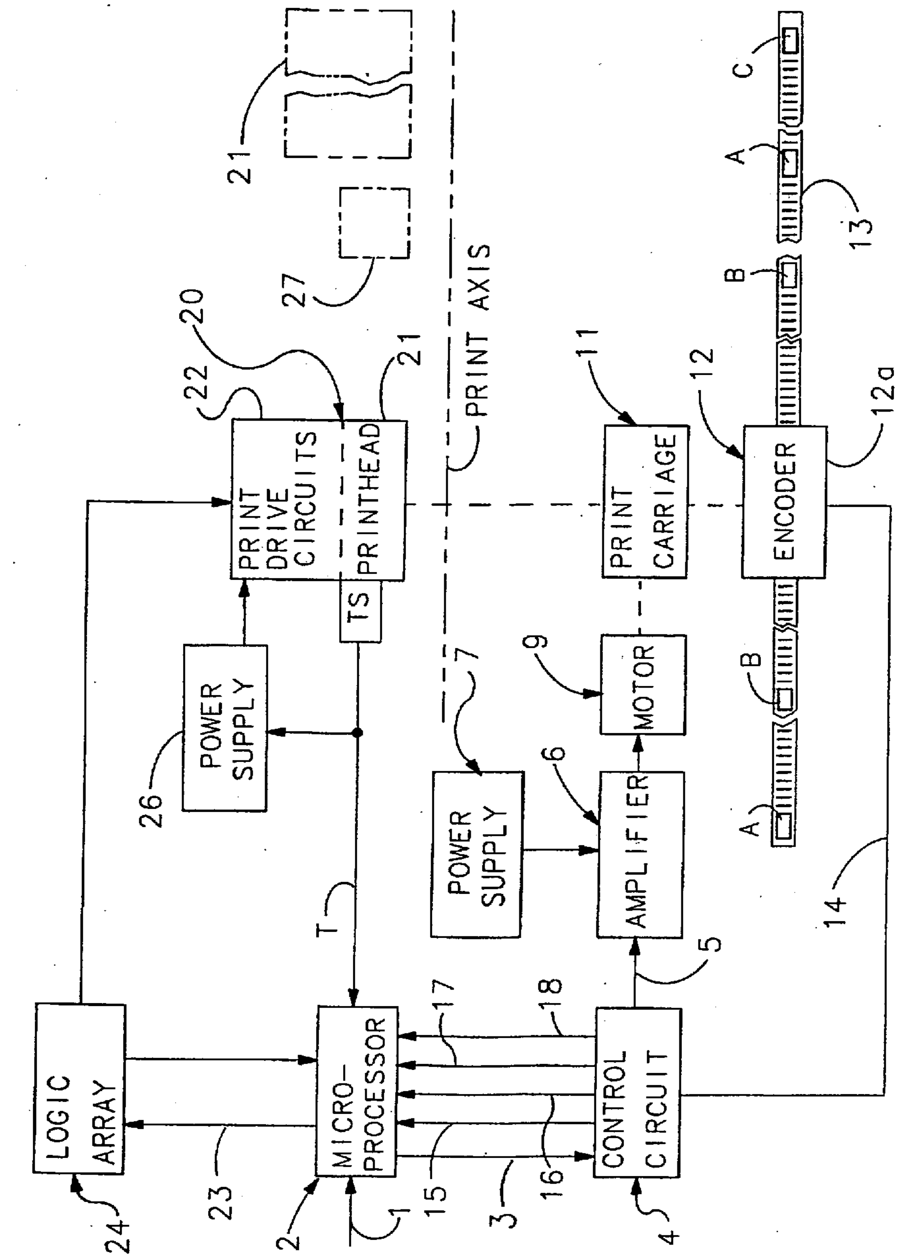
Primary Examiner—Joseph W. Hartary

[57] ABSTRACT

Thermal inkjet printhead temperature control is provided in a temperature control system responsive to printhead temperature, which in the presence of printhead overheating selectively causes the printhead to stand idle, or, if multiple nozzles are available, shifts to a nozzle which, is not overheated, which in the event a nozzle is unused for some time and the dye transport agent may have evaporated leaving a viscous plug in the nozzle, employs warm up pulsing and/or nozzle spitting to clear the nozzles, and which when the temperatures of the nozzle is below acceptable printing temperatures, employs nozzle pulsing for warm up and/or nozzle spitting to clear the nozzles, all such decisions and actions being provided in advance of beginning a printing operation.

4 Claims, 4 Drawing Sheets





PRINT DRIVE CIRCUITS
PRINTHEAD
TS
POWER SUPPLY
PRINT AXIS
PRINT CARRIAGE
ENCODER
MOTOR
AMPLIFIER
POWER SUPPLY
LOGIC ARRAY
MICRO-PROCESSOR
CONTROL CIRCUIT
T
A
B
C
1
2
3
4
5
6
7
9
11
12
12a
13
14
15
16
17
18
20
21
22
23
24
26
27

FIG 1

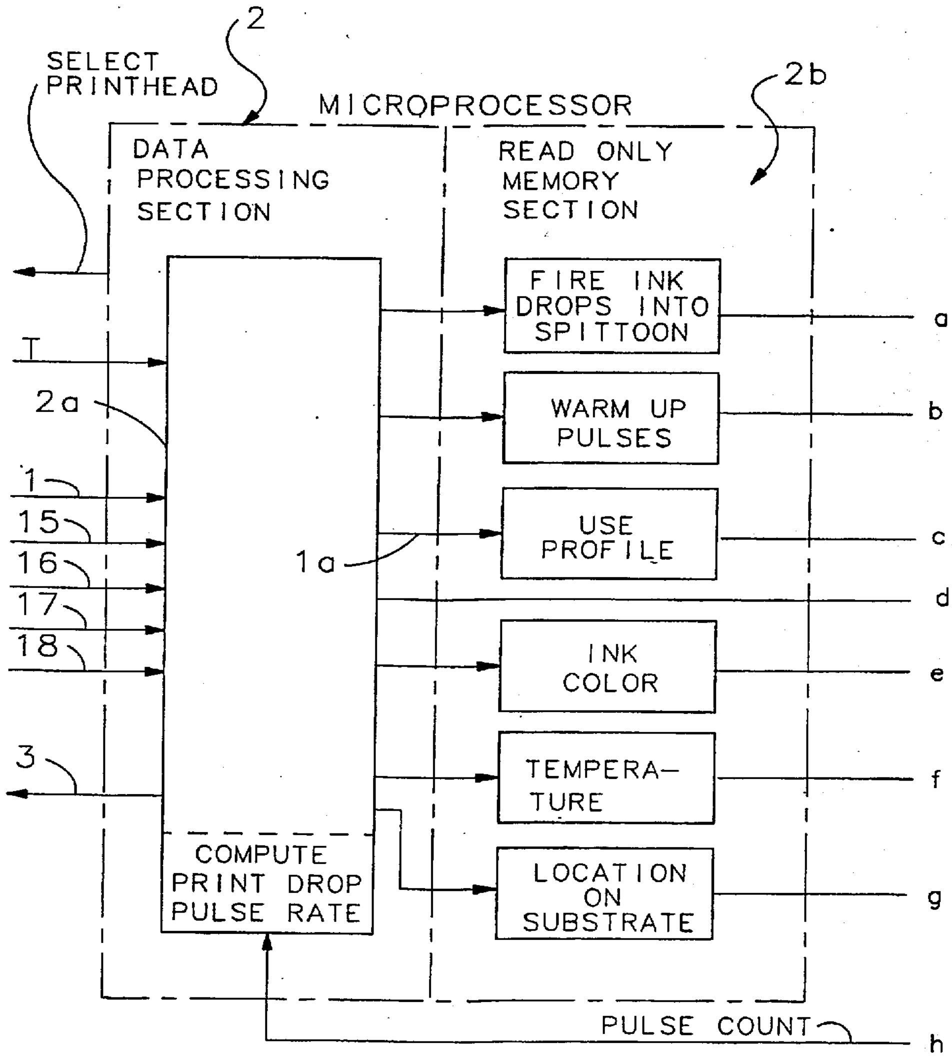
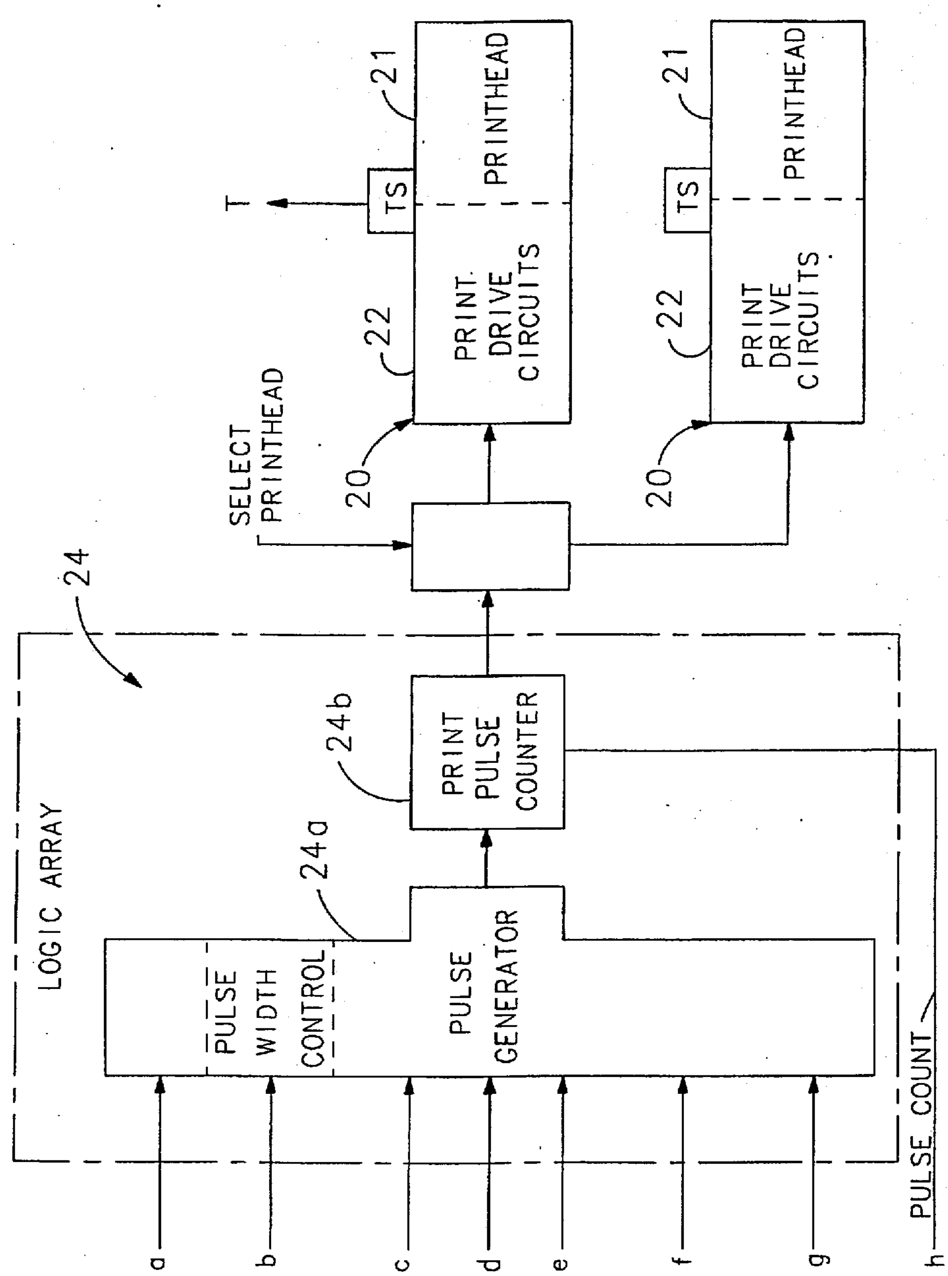

2
SELECT PRINTHEAD
MICROPROCESSOR
2b
DATA PROCESSING SECTION
READ ONLY MEMORY SECTION
FIRE INK DROPS INTO SPITTOON
a
T
2a
WARM UP PULSES
b
1
15
16
17
18
1a
USE PROFILE
c
d
INK COLOR
e
3
TEMPERA-TURE
f
COMPUTE PRINT DROP PULSE RATE
LOCATION ON SUBSTRATE
g
PULSE COUNT
h

FIG 2A



PRINTHEAD
TS
T
PRINT DRIVE CIRCUITS
21
22
20
SELECT PRINTHEAD
24
LOGIC ARRAY
PRINT PULSE COUNTER
24b
24a
PULSE WIDTH CONTROL
PULSE GENERATOR
PULSE COUNT
a
b
c
d
e
f
g
h

FIG 2B

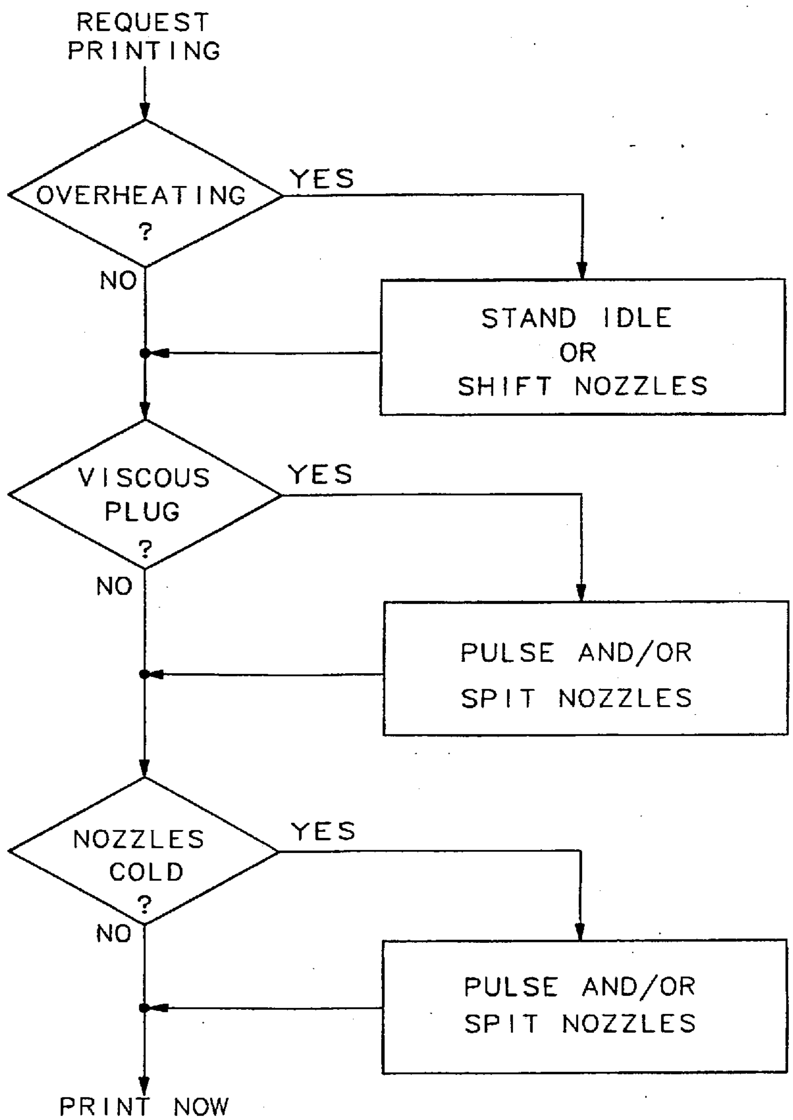

REQUEST PRINTING
OVERHEATING ?
YES
NO
STAND IDLE OR SHIFT NOZZLES
VISCOUS PLUG ?
YES
NO
PULSE AND/OR SPIT NOZZLES
NOZZLES COLD ?
YES
NO
PULSE AND/OR SPIT NOZZLES
PRINT NOW

FIG 3

THERMAL INKJET PRINTHEAD TEMPERATURE CONTROL

TECHNICAL FIELD

This invention relations to thermal inkjet types of printers for producing printed text and/or graphics and more particularly to arrangements for controlling the uniformity of the ink drops in such printers by providing a control of the temperature of the printhead or pen.

BACKGROUND ART

The appearance of printed text or graphics produced by thermal inkjet print heads varies if the viscosity of the ink changes. Viscosity is affected by the printhead temperature which in turn varies with the use profile of the printhead and the temperature environment in which the printer operates.

One prior art approach taken in dealing with this problem has been to provide a spittoon into which ink drops are ejected prior to commencing printing. The purpose of this is twofold. First such ink drop ejection tends to clear viscous plugs from the nozzle of the thermal inkjet printhead and second, this preliminary use of the printhead provides a warm up interval, hopefully to achieve a printhead temperature at or near a desired temperature for printing purposes.

Another prior art effort in dealing with this problem has been to provide a multi-grade ink in which the change is viscosity over a limited range of printhead operating temperatures would not result in significant degradation of print quality.

DISCLOSURE OF THE INVENTION

While such prior art developments have provided improvements in the quality of printed text, further improvements in thermal inkjet printhead operation are achieved in accordance with this invention, in arrangements providing a control of thermal inkjet printhead temperature. Normal nozzle substrate temperatures for satisfactory printhead operation are about 40° C. Variations of about ±5° C. can be tolerated. Many things influence the temperature of the nozzle, these include: the ambient temperature of the environment, the amount of use a particular nozzle gets, the location of a nozzle on the nozzle substrate, i.e., near an edge or toward the center of the nozzle substrate.

In addition, certain dyes (and dye transport agents) are more sensitive to temperature than others. The magenta nozzles may be more sensitive to low temperatures than the black nozzles, for instance.

Therefore, the determination of temperature at or near each individual nozzle in a nozzle substrate is necessary to optimize printhead performance and hence to maximize print quality.

The printhead temperature is determined by several means. One is by placing temperature sensing transducers on the substrate for each nozzle. Alternatively a thermistor is placed on the printed circuit board to which the printhead is attached. This assembly is mounted on the printer carriage. Using the output of the thermistor a close estimate of the printhead temperature is achieved. Thermal models of the pens or printheads are provided and these are used in conjunction with printhead temperature sensors to provide the information useful in controlling the printhead temperature. Profiles of the use of each nozzle are developed. These profiles when compared with a thermal model provide information useful in controlling head temperature.

Temperature compensation and control is provided for both low printhead temperature and high printhead temperature.

At low temperatures low energy pulses are sent to a nozzle to heat it. These pulses are below the threshold which would cause a drop of ink to be fired. The number of pulses used in this warm up process is based on the nozzle's temperature, the location of the nozzle in the substrate, the dye (color) in the nozzle, and the use profile of the nozzle.

Another warming method which is employed is to fire some drops of ink from the nozzle into a spittoon which is located near the writing area but in a position outside of the writing area. The number of drops fired into this spittoon are based upon the temperature which is sensed, the nozzle location on the substrate, the color of the ink in the nozzle and the use profile of the nozzle.

At high temperature, the use profile and the temperature sensors are monitored to see if a particular nozzle exceeds its operable range. If this is the case, printing is stopped until the temperature drops or in the alternative where more than one nozzle is on the substrate another nozzle is used.

If a nozzle is unused for some time, the dye transport agent can evaporate, leaving a viscous plug in the nozzle. This evaporation is both temperature and time dependent. The nozzle use and temperature profiles are used in this situation to indicate when a nozzle needs to be cleared by firing ink drops into the spittoon. Low energy pulses which are below the level needed to fire ink drops are also used to warm and thin the viscous plugs depending upon the temperature and nozzle use profiles. Pulsing may be used independently of spitting or may be used prior to spitting to facilitate clearing the nozzles.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be further understood by reference to the following specification when considered in conjunction with the accompanying drawings, in which:

FIG. 1 is a block diagram of an improved thermal inkjet printer control system, including provisions for controlling the temperature of the printhead, in accordance with the principles of this invention;

FIGS. 2A and B are block diagrams illustrating details of the printhead temperature control system of this invention; and

FIG. 3 is a flow chart illustrating the decision making process in the different functional modes of operation.

BEST MODES FOR CARRYING OUT THE INVENTION

FIG. 1 is a block diagram of a thermal inkjet printhead temperature control system embodying the principles of this invention. Print data may be supplied from an instrumentality such as a computer (not shown). Such print data is applied as input via a bus 1 to a microprocessor 2. In response to this input, as well as other inputs, yet to be described, the microprocessor produces control signals which are coupled by a bus 3 to a control circuit 4 which has multiple functions. The control circuit 4 produces a pulse width modulated signal which is coupled by a circuit 5 to a pulse width modulation amplifier 6 supplied with power from a power source 7. The amplifier 6 transforms and ampli-

fies the input signal thereto to produce a drive voltage coupled by a circuit **8** to a motor **9**. The motor **9** in this application is a DC motor functioning as a print carriage drive motor. The motor **9** drives a mechanism **10**, such as a pulley and belt system, connected to a print carriage **11**, to move the carriage in its axis. An encoder **12**, comprising an encoder body **12***a* and an encoder scale **13** responds to carriage motion. The encoder scale **13** is secured at its ends to the printer chassis (not shown) in a position spanning and paralleling the carriage axis. The encoder body **12***a* which is mounted on the printer carriage, includes an optical scale detector therewithin which scans the tape as the carriage moves in its axis. Scale count signals, as well as signals indicative of start-of-print or end-of-print, from print limit bands B, carriage sweep limit signals from sweep limit bands A, etc., which are produced by the encoder, are coupled as feedback via circuit **14** to the control circuit **4**. Control circuit **4**, using the encoder signals, produces ink drop firing rate signals, coupled via a circuit **15** to the microprocessor for controlling ink drop firing, produces scale count signals coupled to the microprocessor via a bus **16** for motor control, produces print limit signals from print bands B of the scale, and produces carriage sweep limit signals from the sweep limit bands A of the scale, respectively.

The microprocessor compares the desired carriage position, which it generates in response to its input **1** with the carriage position derived from encoder feedback while scanning the scale divisions, and then computes the required control for the motor. This is an incremental process and is repeated, in one embodiment of this invention, at 200 times per second. This computation of motor control voltage provides the basis for control of print carriage speed between the print limit bands B within which printing takes place.

The encoder which is shown, is a single channel incremental position encoder. This encoder functions as the feedback element in the control system. Its description here is believed to be sufficient for an understanding of this invention. This single channel encoder however, is the subject of a co-pending application of Mark W. Majette, et al, Ser. No. 07/056,936, filed 06-01-87, entitled Single Channel Encoder and assigned to the assignee of this invention. The subject matter of this single channel encoder application is included herein by reference.

The print carriage control system of FIG. **1** is the subject matter of a co-pending application of Mark W. Majette, et al, Ser. No. 07/077,575, filed 07-23-87, entitled Single Channel Encoder System and assigned to the assignee of this invention. The subject matter of this single channel encoder control system patent application is also included herein by reference.

In one practical embodiment of this invention, there are 90 scale divisions per inch on the encoder scale. The control circuit **4** doubles this to provide 180 pulse counts per inch required by the print heads for print drop firing. Control circuit **4** also quadruples the scale division pulse counts to provide 360 pulse counts per inch of scale required by the motor control.

When leaving the printing zone, the carriage is decelerated in the space between the print limit bands B and the sweep limit bands A. During printing, the carriage is stopped and reversed in the sweep limit bands A, and then accelerated to print speed between the sweep limit band A and the print limit band B. At the print limit band B, start-of-print is initiated resulting in the production of the print drop firing signals coupled by the bus **15** to the microprocessor.

A printhead assembly **20** comprising a printhead **21** and print drive circuit **22** is mounted on the print carriage and moves with the print carriage in the axis. The printhead **21** is of the thermal inkjet type. It may be a single color or a multi-color printhead. A nozzle array is provided for each color of ink in the printhead. Thermal excitation for each nozzle in each nozzle array is used to fire the ink drops. This thermal excitation in the form of voltage pulses is provided by the print drive circuit **22**. Such arrangements are well known. The print drive circuits **22** conventionally comprise a printed circuit board to which the printhead is connected, forming the printhead assembly **20**.

The microprocessor produces print data signals for controlling the firing of the printhead nozzles. The print data signals provide information for pulse formation, for nozzle firing, for printing text and/or graphics and for maintaining uniformity of ink drops by controlling printhead temperature. In accomplishing this, the print data output of the microprocessor is coupled via a bus **23** to a logic array circuit **24**. The logic array circuit comprises a pulse generator and a pulse counter with provisions for pulse width control. The logic array circuit produces pulses coupled to the print drive circuits for selectively, and individually firing the nozzles of the print heads in a sequence to produce the text and/or graphics of the print data **1** as the printer carriage moves through the print zone between the print limit bands B on the scale.

Temperature compensation is provided in part by measuring the temperature of the printhead. This may be done by providing a nozzle substrate having temperature sensitivity, or by placing a temperature sensor TS on the nozzle substrate, or by locating a temperature sensor TS such as a thermistor on the carriage printed circuit board or on the printhead. Such temperature sensors are used to provide the input needed to estimate the printhead temperature, which, in turn, can be used to control the printhead temperature, using inexpensive electronics. As indicated in FIG. **1** the output of the temperature sensor TS is connected to the microprocessor **2**. The print drive circuits are supplied with power by a power supply **26**. The output of the temperature sensor TS is also coupled as a control input to the power supply **26** and is used to regulate print pulse energy inversely proportionally to printhead or nozzle temperature. Thus, temperature sensing at the printhead is used directly to control the power supply so that the pulse energy which is applied for firing the ink drops results in uniformity of the ink drops. In the microprocessor, the indication of printhead temperature is employed in a decision making process to determine the temperature condition of the nozzles, i.e., whether the nozzles are cold or whether the nozzles are overheating and is used with processor based information as to the location of the nozzles on the substrate, the color of the ink in a particular printhead and the use profile of that printhead, for providing input to the logic array circuit **24** for producing print pulses for firing the nozzles of that particular printhead, to maintain uniformity in the ink drops which are fired.

The organizational concept of that aspect of this temperature control system is illustrated in FIG. **2**. In FIG. **2** the microprocessor **2** is shown in dot-dash outline. For the purpose of this description, it comprises a data processing section **2***a* and a read only memory

section 2*b*. The data processing section uses the print data instructions on bus 1 to provide input by a bus 1*a* to a pulse generator 24*a* in the logic array circuit 24 for printing text. Print pulse timing in this respect is determined by the microprocessor using the print drop firing signals on the bus 15 at an input of the data processing section. Thus text is printed by the printhead 21 as the print carriage sweeps in its axis between the print limit bands B on the scale.

The output of the pulse generator 24*a* is coupled to the printhead drive circuits 22 through a print pulse counter 24*b* forming part of the logic array circuit 24. The pulse count output of the print pulse counter is coupled back to the data processing section 2*a* of the microprocessor where it is used to compute the print drop pulse rate of the printhead. This print drop pulse rate is used by the data processor in accessing use profiles in its read only memory section, for providing pulse generating input to the pulse generator so that, for example, in a multi-printhead printer another printhead may be selected for printing. In the alternative, for example, in a single printhead arrangement, excessive temperature alone or rising temperature with a high use profile may be processed by the data processing section of the microprocessor to produce a control to reduce data throughput to prevent the rise in temperature. This concept is tied in with the dwell time between the lines of print data. It is feasible because the printhead temperature time constant is long in comparison with the carriage sweep time in the axis. Thus the microprocessor produces motor control of a character to provide a predetermined dwell time of the carriage in either of the sweep limit bands A on the scale. These dwell intervals may take place at the end of each carriage sweep or at the end of selected carriage sweeps to control the printhead temperature as required.

Where multiple nozzle arrays are provided on a single substrate, the location of the nozzle array on the substrate has a bearing on its temperature. Similarly ink color is a factor in temperature control because some colors are more sensitive to low temperatures than others.

When the printhead is not in use, it resides in a park or rest position in a limit of carriage movement in which the carriage is removed entirely of the carriage print sweep range. This position is determined by a park band C on the scale, as seen in FIG. 1. When not in use, head temperatures may be below those which are acceptable for printing. The printhead assembly 21 is shown in park position in dot-dash outline in FIG. 1. Adjacent the printhead, in a position toward the adjacent sweep limit band A on the scale, is a spittoon 27, also shown in dot-dash outline. In this circumstance, when a print demand is made, the data processor section of the microprocessor may determine that a viscous plug exists in the printhead nozzle. Thus, when the command is issued for the carriage to move out of park position to perform a printing operation, the microprocessor provides an instruction to the pulse generator 24*a* to produce print drop firing pulses timed to expel print drops into the spittoon as the carriage moves out of the park position for a printing operation. This operation clears any plugs which may exist in the nozzles and additionally provides a degree of warm up depending upon the number of print pulses that have been applied in firing ink drops into the spittoon.

In other circumstances, if the printhead exists in a low temperature situation unacceptable for printing and the use profile is such that no viscous ink plugs exist in the nozzle, warm up pulses for the printhead may be selected. Warm up pulse instructions from the microprocessor, initiated by the data processing section accessing the warm up pulse data of the read only memory section, provides instructions to the pulse width control section of the pulse generator 24*a* to produce warm up pulses. These are time limited voltage bursts which heat but are too short to expel ink from the printhead.

The flow chart of FIG. 3 characterizes these functions of the temperature control system. If there is overheating, the decision is to stand idle as in dwell time in the sweep limit bands A of the carriage, or in a multinozzle single color head assembly, to shift nozzles. In the event of a viscous plug, warming pulses and/or spitting of the nozzles may be employed. In the event the nozzles are cold, nozzle pulsing for warming and/or spitting may be employed. These decisions and actions always precede a following printing operation.

Industrial Applicability

The printhead temperature control for maintaining uniformity and quality of print or graphics is applicable in all thermal inkjet systems.

We claim:

1. A temperature control system for a thermal inkjet printer, having a printer carriage drive, a printer carriage movable by said printer carriage drive across a printing zone between sweep limit positions and movable to and from a rest position in response to print commands, and having a thermal inkjet printhead mounted on said carriage, comprising:

control means including said printer carriage drive and including print drive circuits coupled to said thermal inkjet printhead and responsive to the position of said printer carriage being driven by said printer carriage drive, for producing electrical pulses for firing inkdrops from said thermal inkjet printhead in said printing zone and for stopping said electrical pulses outside of said printing zone;

temperature sensor means for sensing the temperature of said thermal inkjet printhead; and

means responsive to said temperature sensor means for controlling said printer carriage drive of said control means to reduce printer carriage speed above a predetermined sensed temperature, to permit said printhead to cool and thereby to maintain the temperature of said thermal inkjet printhead substantially at said predetermined temperature.

2. The invention according to claim 1, wherein said means responsive to said temperature sensor means comprises:

means for controlling said printer carriage drive of said control means to stop said printer carriage in a sweep limit position and to dwell therein to permit said thermal inkjet printhead to cool when the temperature thereof is above said predetermined temperature at that printer carriage position.

3. The invention according to claim 1, wherein said means responsive to said temperature sensor means comprises:

means responsive to a print command and to said temperature sensor means, as said printer carriage is moved from said rest position by said printer carriage drive of said control means, for causing said control means to apply electric pulses to said thermal inkjet printhead for firing ink drops before reaching a sweep limit position when the tempera-

ture of said thermal inkjet printhead as sensed by said temperature sensor means is below said predetermined temperature.

4. The invention according to claim 1, comprising:

means for counting said electrical pulses;

means for computing a pulse rate from said electrical pulses;

means for determining a quantity representing the

intensity of use, i.e., the use profile of said thermal inkjet printhead from said pulse rate; and

means responsive to said quantity for additionally controlling said control means to control pulse rate as an inverse function of the sensed temperature.

* * * * *

US005107276A

United States Patent [19]

Kneezel et al.

[11] **Patent Number: 5,107,276**

[45] **Date of Patent: Apr. 21, 1992**

[54] **THERMAL INK JET PRINTHEAD WITH CONSTANT OPERATING TEMPERATURE**

[75] Inventors: **Gary A. Kneezel**, Webster; **Thomas A. Tellier**, Williamson; **Richard V. LaDonna**, Fairport, all of N.Y.

[73] Assignee: **Xerox Corporation**, Stamford, Conn.

[21] Appl. No.: **572,075**

[22] Filed: **Aug. 24, 1990**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 375,162, Jul. 3, 1989, abandoned.

[51] **Int. Cl.**[5] **B41J 2/05**

[52] **U.S. Cl.** .... **346/1.1; 346/140 R**

[58] **Field of Search** 346/140, 1.1

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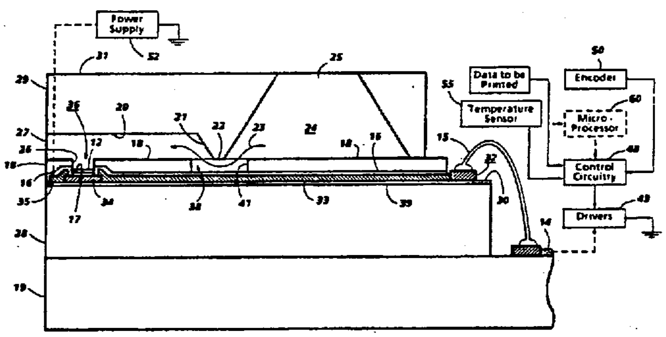
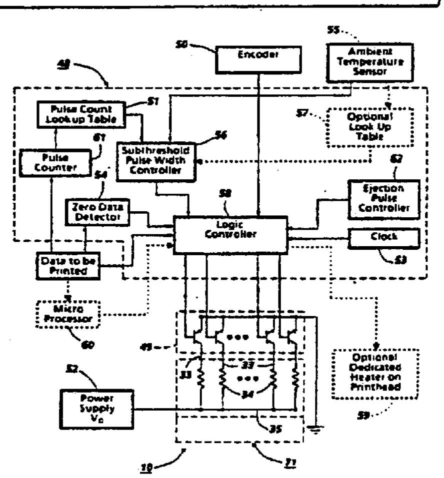
Primary Examiner—Joseph W. Hartary
Attorney, Agent, or Firm—Robert A. Chittum

[57] **ABSTRACT**

A thermal ink jet printer is disclosed which has a printhead that is maintained at a substantially constant operating temperature during printing. Printing on demand is accomplished by the ejection of ink droplets from the printhead nozzles in response to energy pulses selectively applied to heating elements located in ink channels upstream from the nozzles which pulses vaporize the ink to form temporary bubbles. To prevent printhead temperature fluctuations during printing, especially in translatable carriage printers, the heating elements not being used to eject droplets are selectively energized with energy pulses having insufficient magnitude to vaporize the ink.

23 Claims, 10 Drawing Sheets





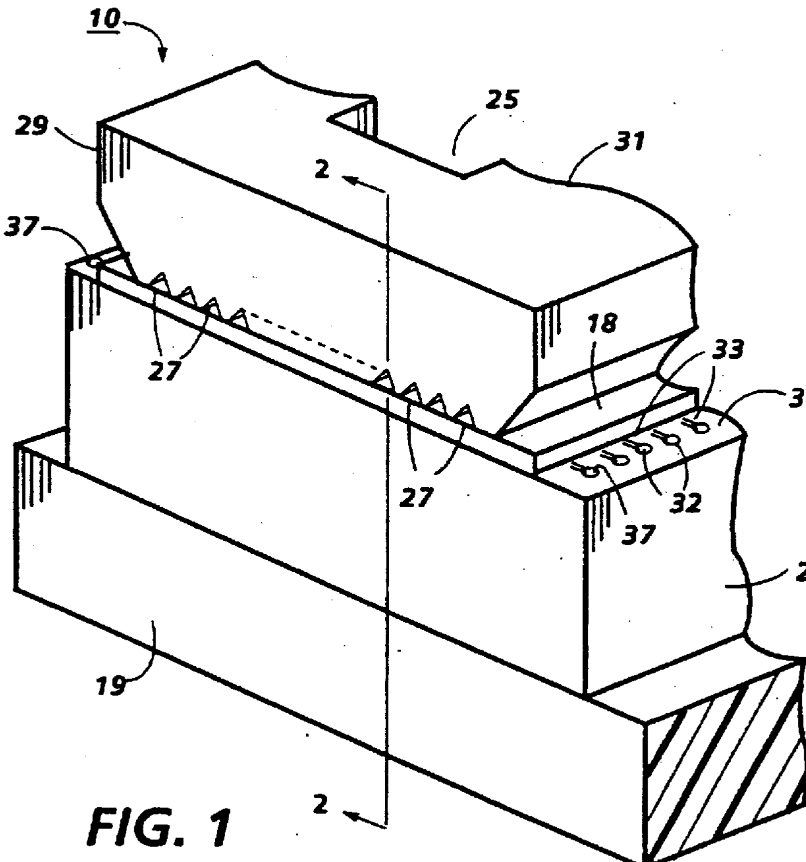
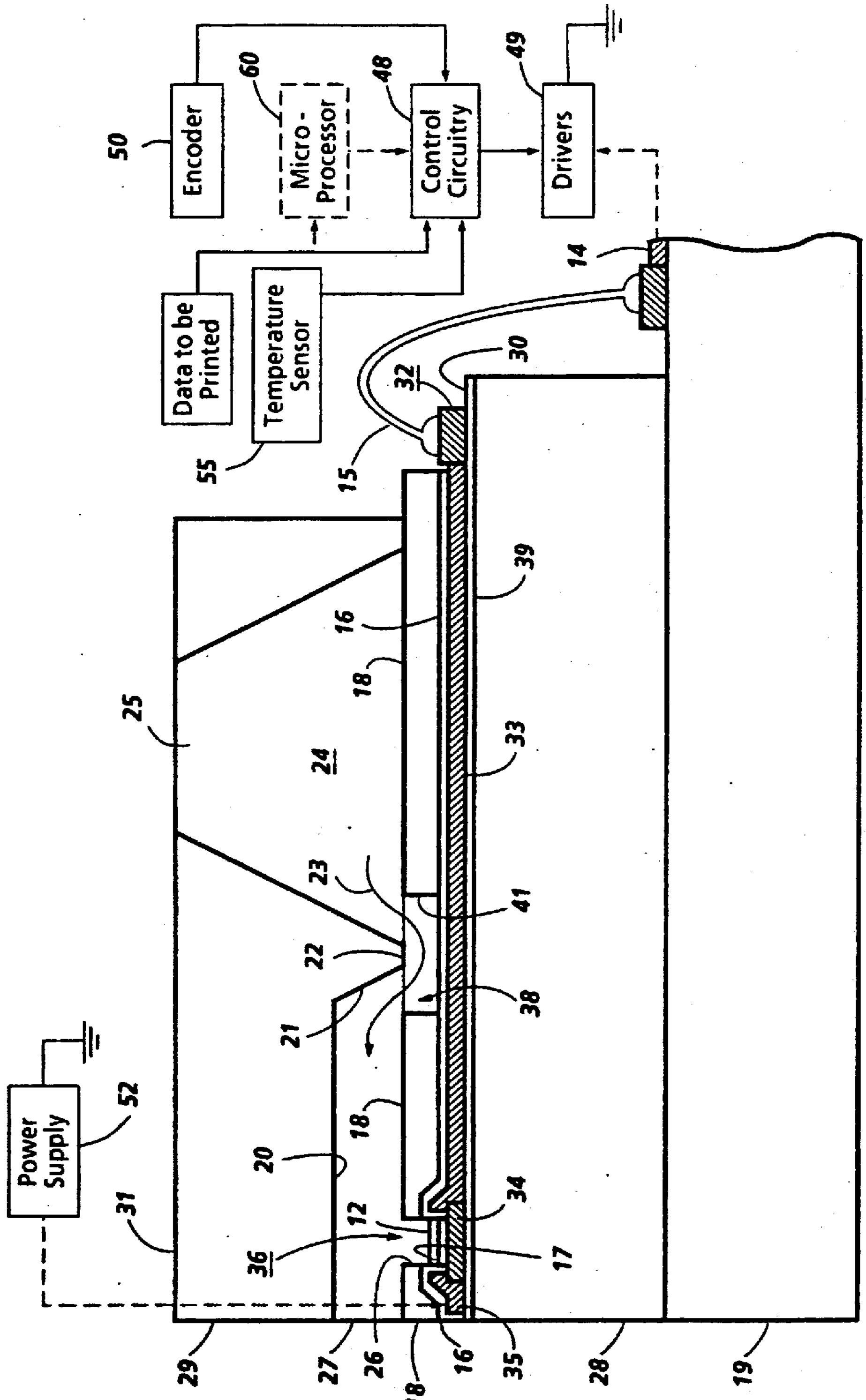


FIG. 1
(Prior Art)



Encoder
50
Micro-Processor
60
Control Circuitry
48
Drivers
49
Data to be Printed
Temperature Sensor
55
Power Supply
52
14
30
32
15
39
16
18
25
24
33
23
41
22
38
21
20
31
12
34
36
17
26
29
27
18
16
35
28
19

FIG. 2

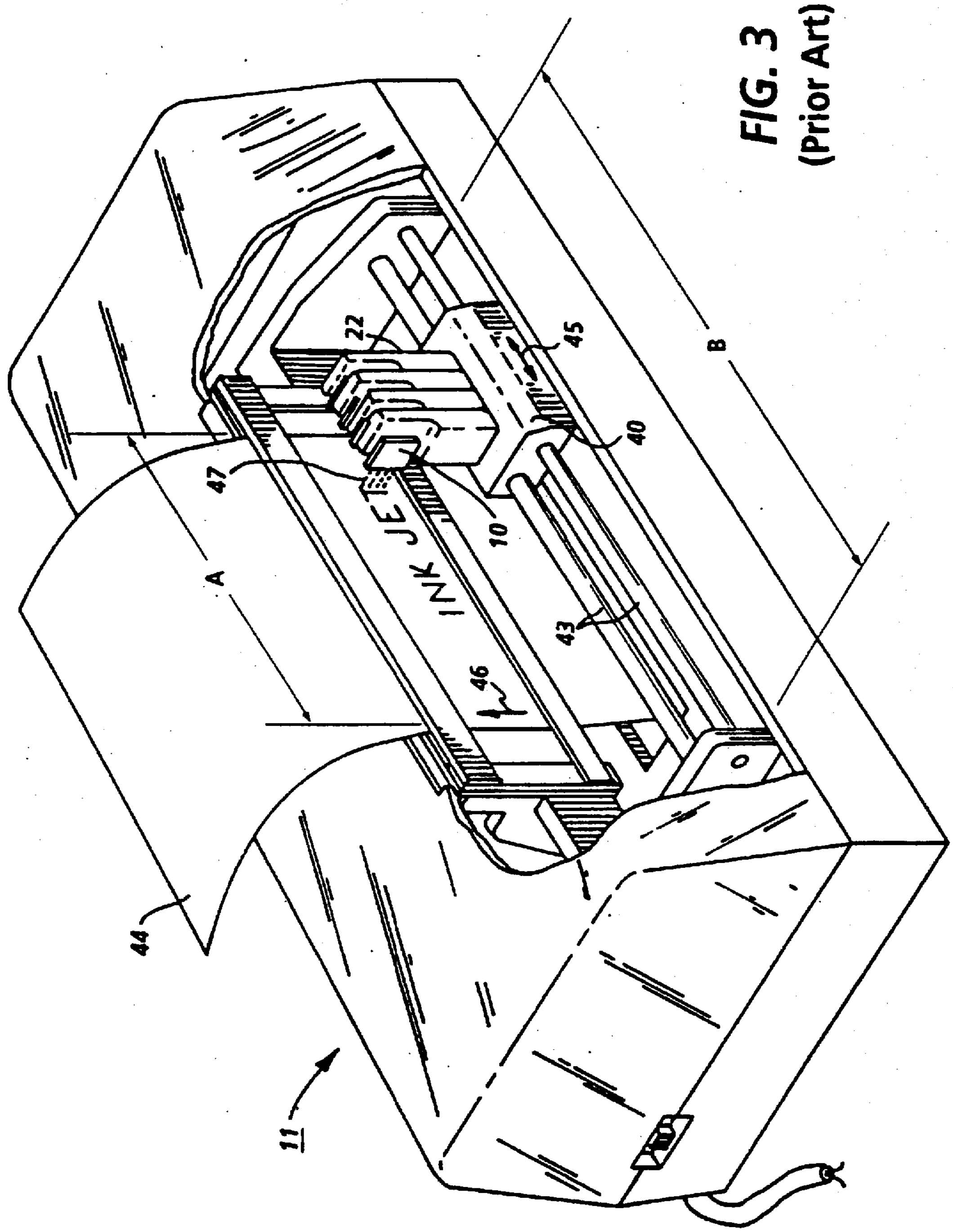
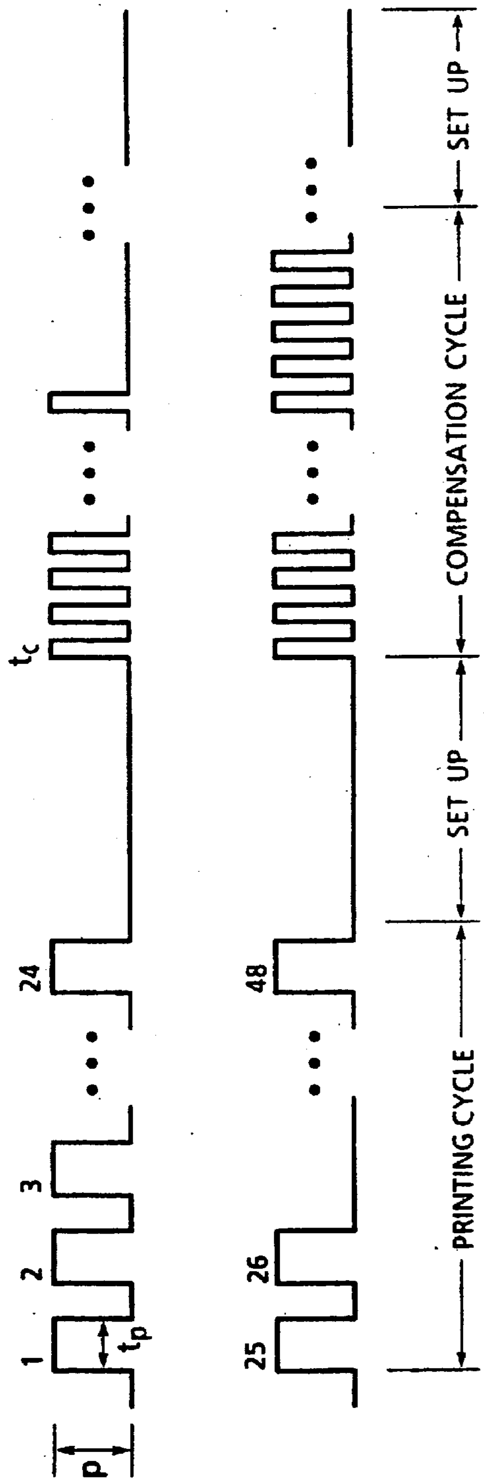


FIG. 3
(Prior Art)



p
1
t_p
2
3
24
t_c
25
26
48
PRINTING CYCLE
SET UP
COMPENSATION CYCLE
SET UP

FIG. 4

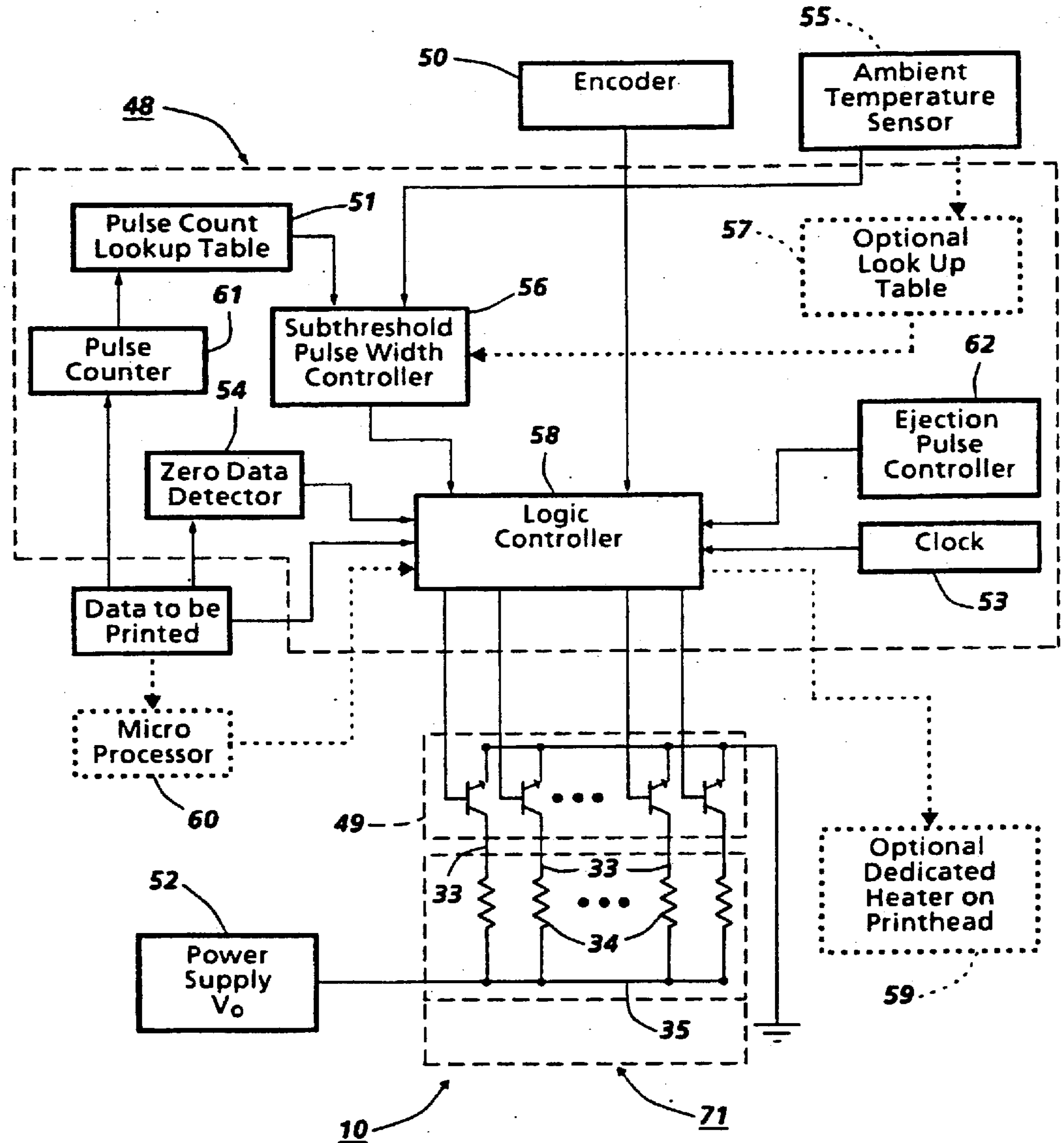
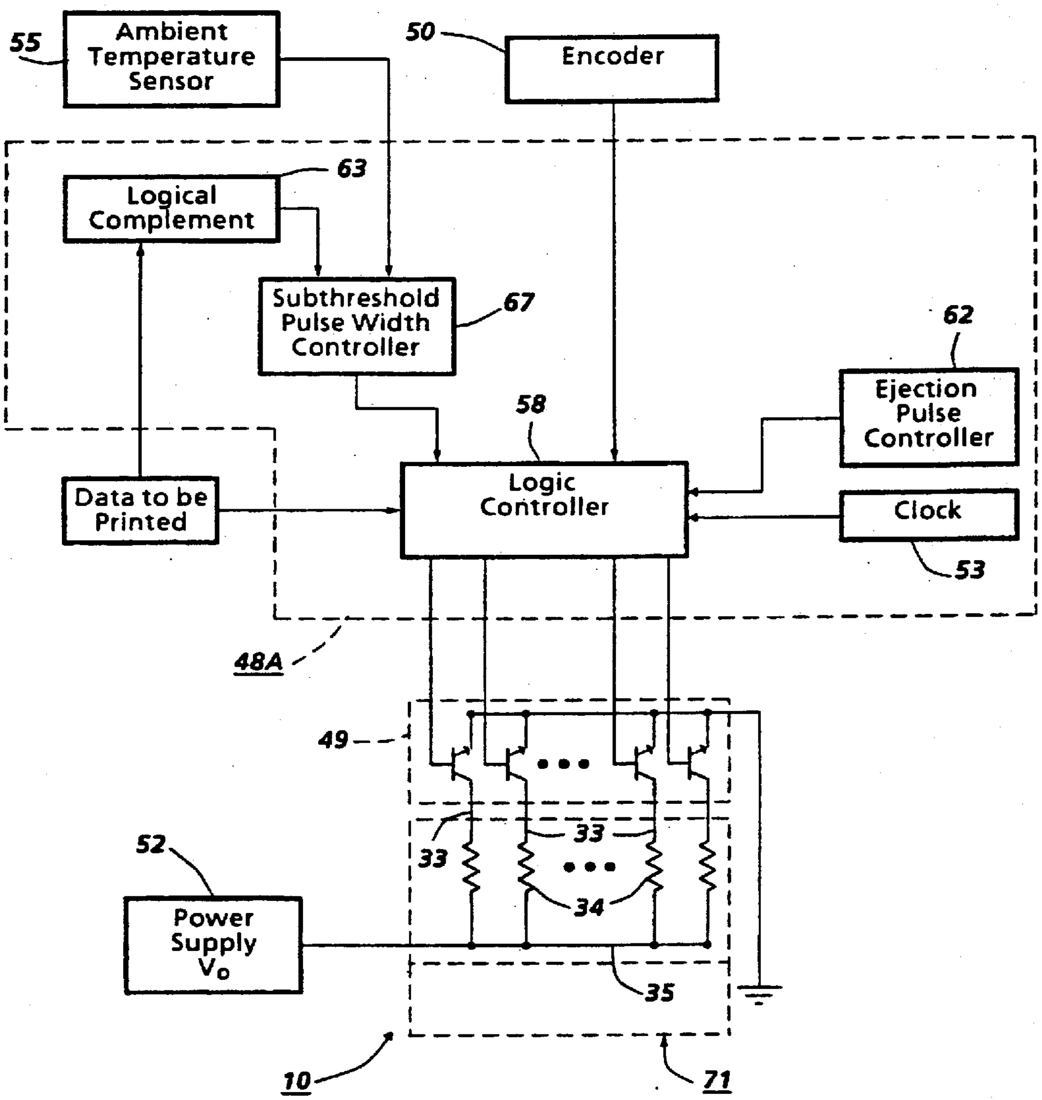

55
Ambient Temperature Sensor
50
Encoder
48
Pulse Count Lookup Table
51
57
Optional Look Up Table
61
56
Pulse Counter
Subthreshold Pulse Width Controller
62
54
58
Ejection Pulse Controller
Zero Data Detector
Logic Controller
Clock
53
Data to be Printed
Micro Processor
60
49
33
33
34
52
Power Supply V_o
35
Optional Dedicated Heater on Printhead
59
10
71

FIG. 5A



55
Ambient Temperature Sensor
50
Encoder
63
Logical Complement
Subthreshold Pulse Width Controller
67
62
Ejection Pulse Controller
58
Logic Controller
Data to be Printed
Clock
53
48A
49
33
33
34
52
Power Supply V_o
35
10
71

FIG. 5B

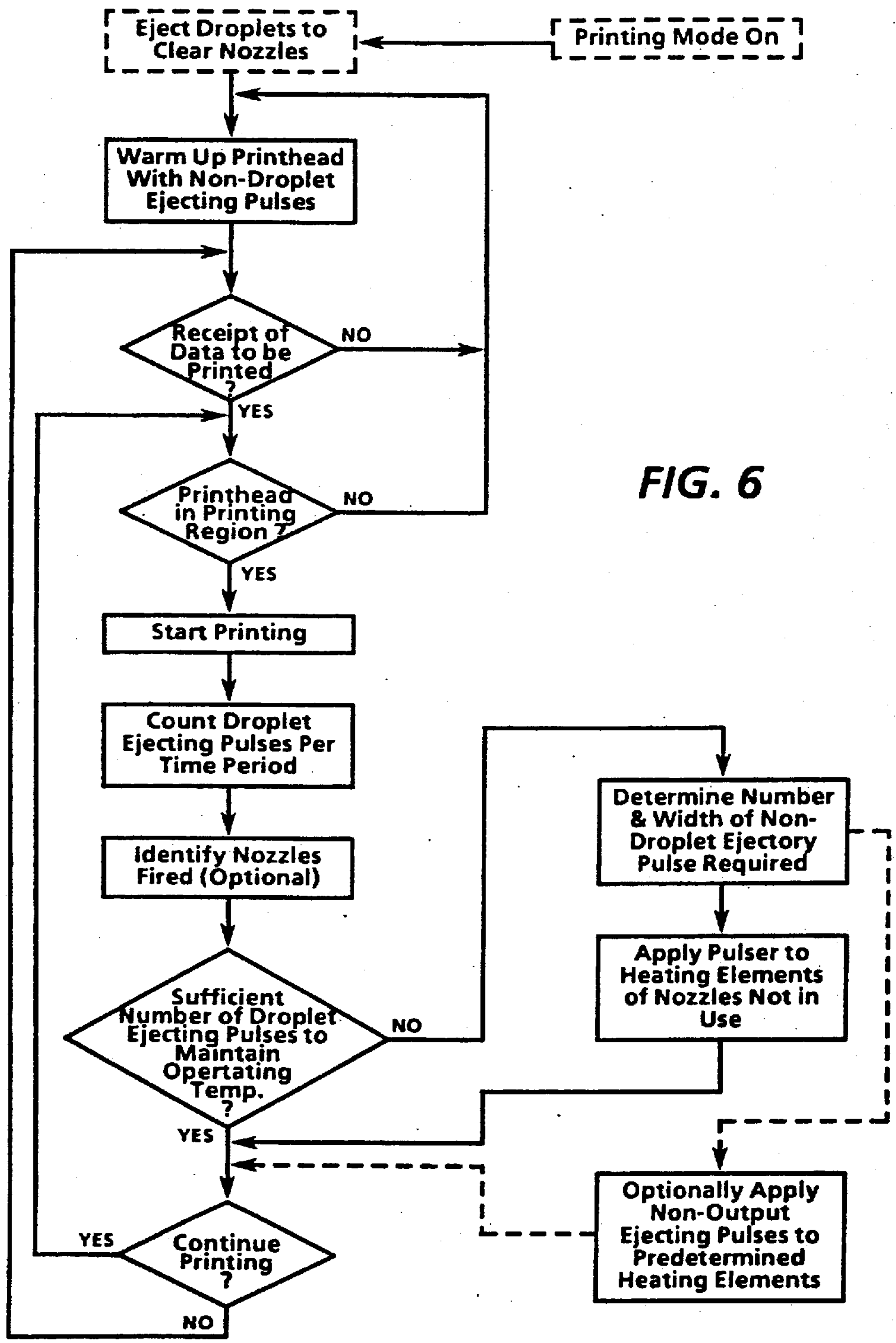
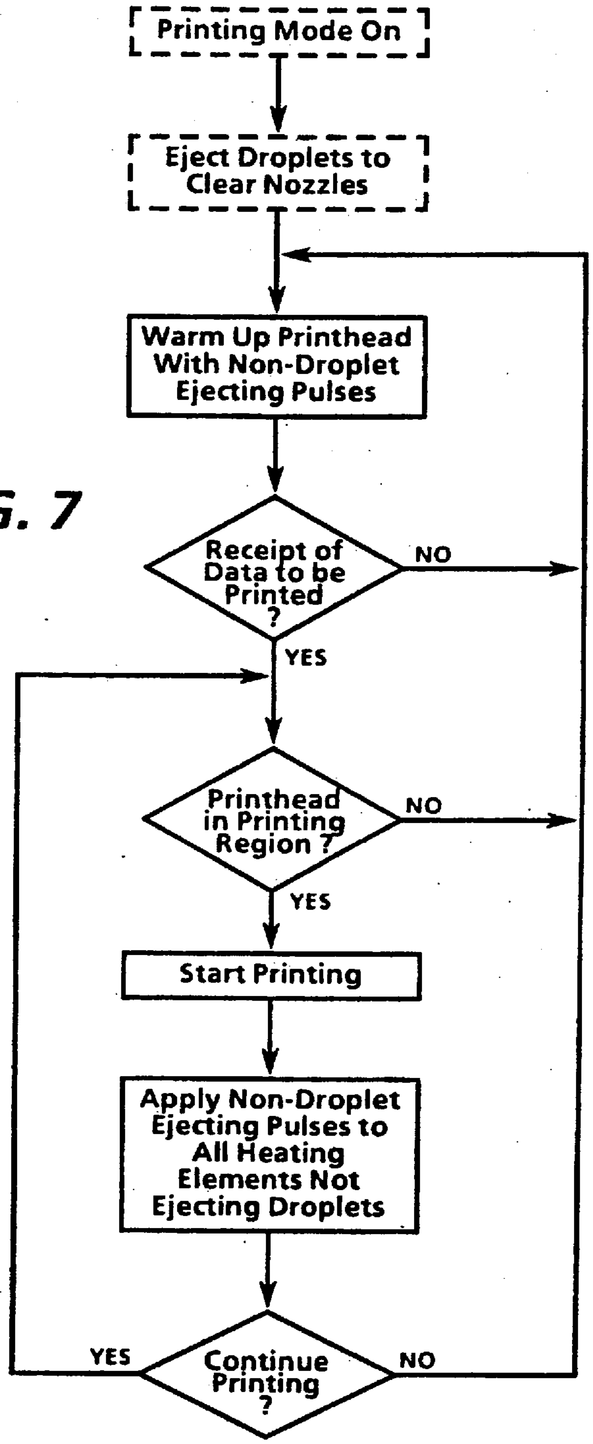

Eject Droplets to Clear Nozzles
Printing Mode On
Warm Up Printhead With Non-Droplet Ejecting Pulses
Receipt of Data to be Printed ?
NO
YES
Printhead in Printing Region ?
NO
YES
Start Printing
Count Droplet Ejecting Pulses Per Time Period
Identify Nozzles Fired (Optional)
Sufficient Number of Droplet Ejecting Pulses to Maintain Opertating Temp. ?
NO
YES
Determine Number & Width of Non-Droplet Ejectory Pulse Required
Apply Pulser to Heating Elements of Nozzles Not in Use
Optionally Apply Non-Output Ejecting Pulses to Predetermined Heating Elements
Continue Printing ?
YES
NO

FIG. 6

FIG. 7


Printing Mode On
Eject Droplets to Clear Nozzles
Warm Up Printhead With Non-Droplet Ejecting Pulses
Receipt of Data to be Printed ?
NO
YES
Printhead in Printing Region ?
NO
YES
Start Printing
Apply Non-Droplet Ejecting Pulses to All Heating Elements Not Ejecting Droplets
Continue Printing ?
YES
NO

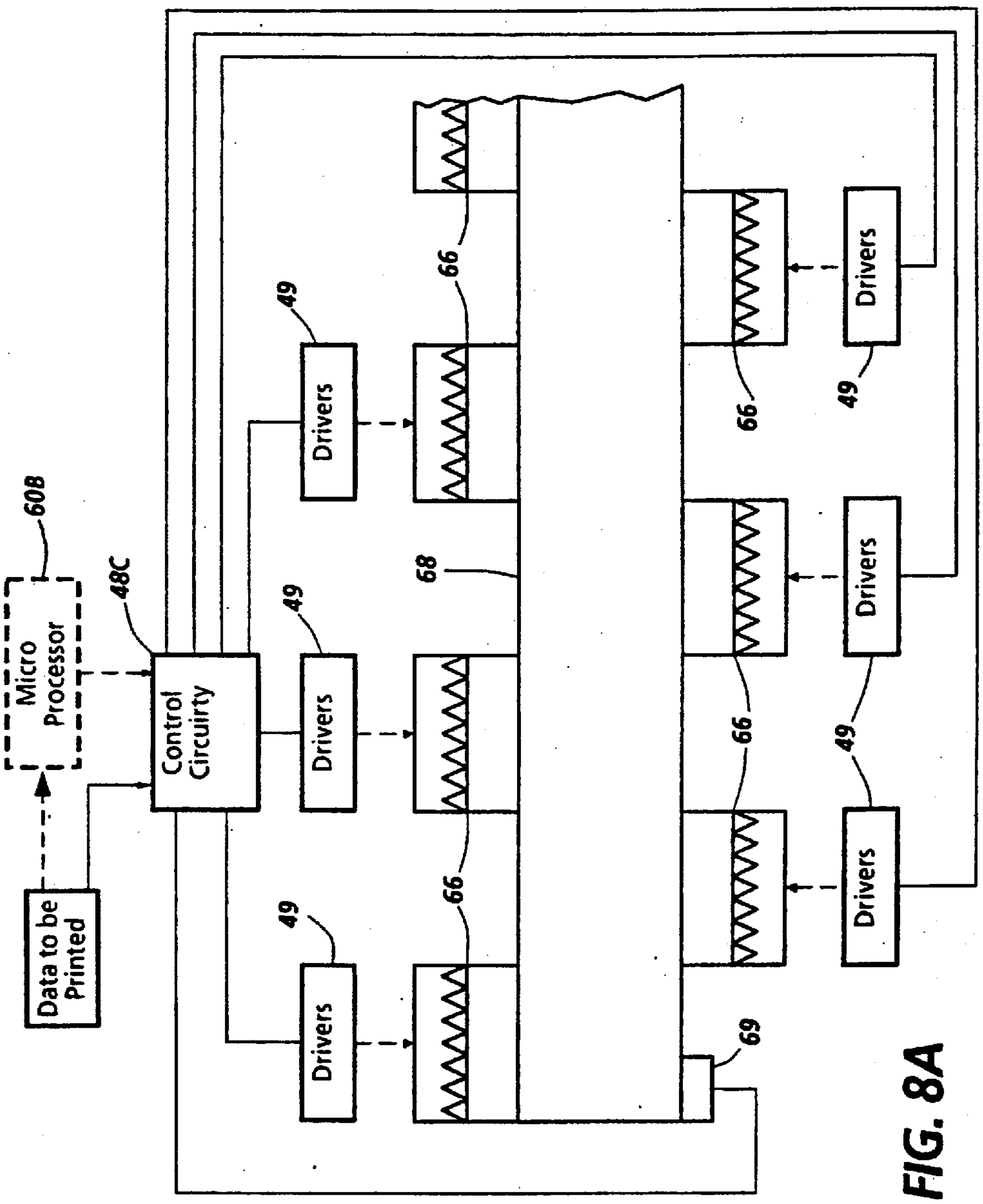

Data to be Printed
Micro Processor
60B
Control Circuitry
48C
Drivers
49
66
68
69

FIG. 8A

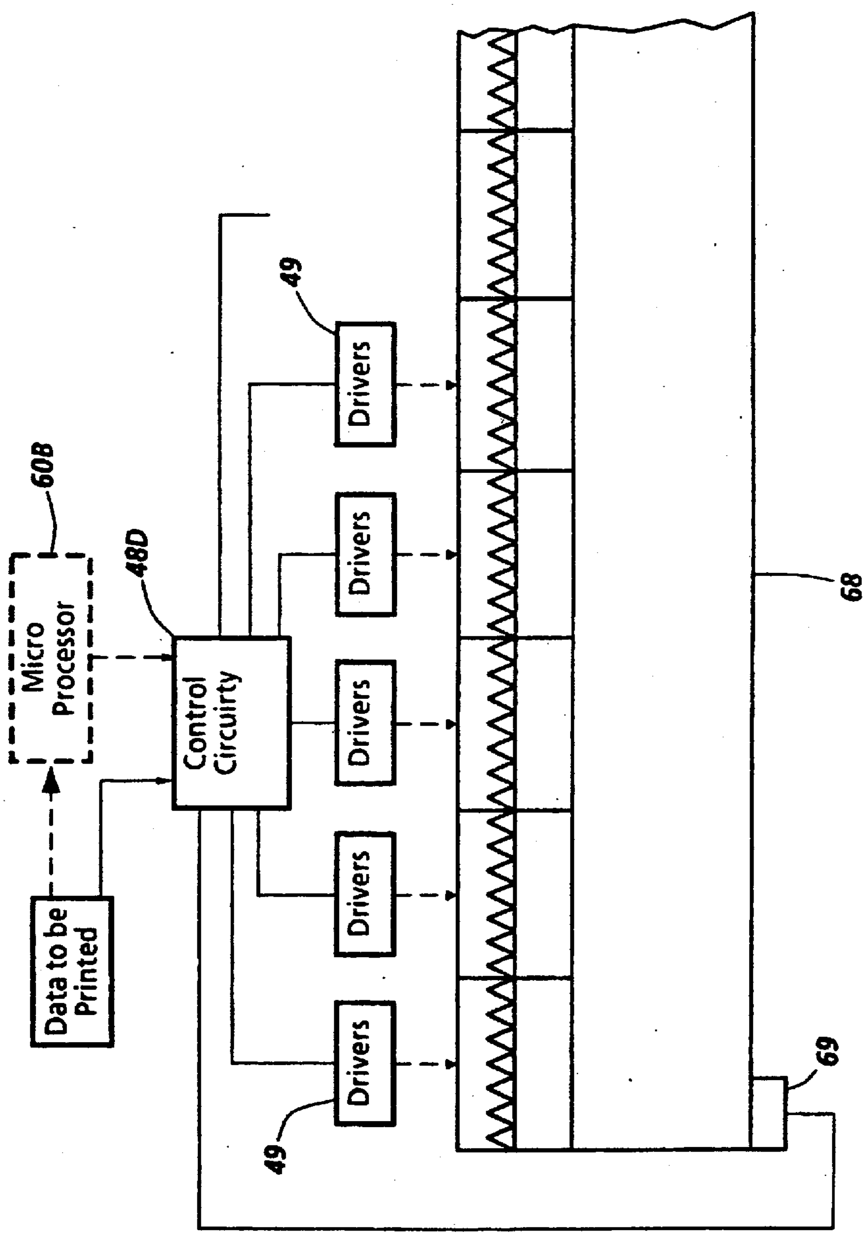

Data to be Printed
Micro Processor
60B
48D
Control Circuirty
Drivers
Drivers
Drivers
Drivers
Drivers
49
49
68
69

FIG. 8B

THERMAL INK JET PRINTHEAD WITH CONSTANT OPERATING TEMPERATURE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This application is a continuation-in-part application of the application Ser. No. 07/375,162 filed Jul. 3, 1989 now abandoned.

This invention relates to thermal ink jet printing devices and, more particularly, to improved printheads which are maintained at a constant operating temperature so that droplet or pixel size does not vary with temperature.

2. Description of the Prior Art

Thermal ink jet printing is generally a drop-on-demand type of ink jet printing which uses thermal energy to produce a vapor bubble in an ink-filled channel that expels a droplet. A thermal energy generator or heating element, usually a resistor, is located in the channels near the nozzle a predetermined distance therefrom. The resistors are individually addressed with an electrical pulse to momentarily vaporize the ink and form a bubble which expels an ink droplet. As the bubble grows, the ink bulges from the nozzle and is contained by the surface tension of the ink as a meniscus. As the bubble begins to collapse, the ink still in the channel between the nozzle and bubble starts to move towards the collapsing bubble, causing a volumetric contraction of the ink at the nozzle and resulting in the separating of the bulging ink as a droplet. The acceleration of the ink out of the nozzle while the bubble is growing provides the momentum and velocity of the droplet in a substantially straight line direction towards a recording medium, such as paper.

Thus, thermal ink jet devices operate by pulsing heating elements in contact with ink so that bubbles are nucleated, ejecting ink droplets toward the paper. It has been found during print tests that print quality is affected as the device heats up. In particular, if the device heats up too high (e.g., during extended high density printing), then it tends to lose prime, and one or more ink channels of the printhead cease to expel droplets. A less catastrophic defect, but still one that degrades print quality, is the increase in printed spot or pixel size as a function of device temperature. Through study of this phenomenon, it has been found that both the mass and velocity of the droplet increase with device temperature and that both the mass and velocity contribute to increased pixel size on the paper. For the carriage type ink jet printer with sufficiently high printing density, the spot size increases as the carriage traverses the page. Then as it pauses at the end of travel and reverses direction, it cools slightly, so that the next line or swath printed on the way back has increasing pixel sizes in the opposite direction. This gives rise to light and dark bands, which are most pronounced at the edges of the paper. Similarly, other patterns of high and low density printing are degraded by the increase in pixel size with device temperature.

Many of the prior art devices incorporate a heat sink of sufficient thermal mass and of low enough thermal resistance that the device temperature does not rise excessively. For one example of a thermal ink jet printhead having a heat sink, refer to U.S. Pat. No. 4,831,390 to Deshpande et al. This approach has eliminated the catastrophic printing failure mode. However, to lower the thermal resistance to the heat sink sufficiently that

there is no appreciable device temperature rise in the time scale of a carriage translation in one direction across the paper, it may be necessary to take packaging approaches which would increase the cost or otherwise constrain the printer design in an undesirable way. The temperature rise must be maintained such that negligible image degradation occurs because of thermally induced spot size nonuniformities.

U.S. Pat. No. 4,712,930 to Maruno et al discloses a gradation thermal printhead and a gradation heat transfer printing apparatus which employs an energy controlling means for varying the voltage or pulse width of the signal pulse applied to a thermal printhead. The printing apparatus further has a power supply for the gradation thermal printhead and an energy controlling means for controlling the width of the pulse of the voltage applied to the thermal printhead in accordance with a recording signal.

U.S. Pat. No. 4,536,774 to Inui et al discloses a thermal head drive circuit which improves printing quality by using data from previously printed lines to compute a corrected pulse energy for the line being printed. A pulse energy operator uses data from a heat accumulation state operator, a memory which has data on the pulse energy used in the previously printed lines, and from either a pulse interval detector or a temperature detector.

U.S. Pat. No. 4,712,172 to Kiyohara et al discloses the use of the heating elements to preheat the printhead in the vicinity of the nozzles by subthreshold energy pulses insufficient to expel ink droplets to lower the viscosity of any plug of ink at the nozzles from which water has evaporated. Typically this preheating with subthreshold pulses is done when the ink jet printer is turned on or after it has sat idle for a period of time.

U.S. Pat. No. 4,791,435 to Smith et al discloses a thermal ink jet printhead having temperature sensors to provide the input needed to estimate the printhead temperature, so that the printhead may be kept at the desired predetermined time by slowing down the printing, if it is too hot to cool it off, or adds warming pulses too short to expel droplets, if it is too cold. All decisions and actions are made preceding a printing operation.

U.S. Pat. No. 4,910,528 to Firl et al discloses the use of a temperature sensor to measure the printhead temperature and a microcomputer to determine the pattern of droplets to be printed, so that prior to the commencement of printing, the number of droplets required to print the printed swath is known and used to predict the temperature at the end of swath. If the predicted printhead temperature exceeds a maximum value, the start of printing can be delayed or the printing mode can be modified. If the predicted printhead temperature is below a minimum value, the heating elements are pulsed with non-droplet ejecting current pulses or the sensor can be used as a supplementary heater to warmup the printhead before the start of printing. In conjunction with the current temperature of the printhead as sensed by a sensor thereon, the future printing demand is utilized to predict the printhead temperature at the end of the printing of a swath of information and the printing modified to ensure that the temperature limits are not exceeded.

U.S. Pat. No. 4,719,472 to Arakawa discloses the use of a separate heater and temperature sensor to heat and monitor the temperature of the ink in the reservoir to adjust the viscosity of the ink.

U.S. Pat. No. 4,490,728 to Vaught et al discloses the use of a two part electrical pulse to the heating elements of a thermal ink jet printer. The pulses comprise a precursor pulse insufficient to vaporize the ink following by a nucleation pulse to expel an ink droplet.

SUMMARY OF THE INVENTION

It is the object of the present invention to provide an improved thermal ink jet printhead which maintains itself at a substantially constant operating temperature while printing.

It is another object of the invention to maintain the operating temperature of the printhead constant during a printing mode by supplying supplemental heat thereto by applying non-vapor producing energy pulses to at least some of the heating elements that are not ejecting ink droplets.

In the present invention, a thermal ink jet printhead of the type having an ink supply manifold and a plurality of parallel ink channels with each having a nozzle and a heating element is improved by means for maintaining the printhead at a substantially constant operating temperature. In the printing mode, the printhead ejects ink droplets on demand by the selective energization of the heating elements with energy pulses having sufficient magnitude to vaporize instantaneously the ink in contact with the energized heating element, so that temporary vapor bubbles are formed which eject the ink droplet. The improvement comprises counting the pulses which expel droplets to determine the heat energy applied to the printhead and energization of predetermined heating elements with a sufficient quantity of energy pulses insufficient in magnitude to vaporize the ink at times when the heating elements are not being energized for the ejection of ink droplets to provide supplemental heat, as necessary, to maintain the printhead at a substantially constant operating temperature without the need of continually sensing the printhead temperature. Alternatively, the supplemental heat may be supplied by energizing one or more additional heaters on the printhead which are provided solely to supply heat and which are not used to vaporize ink to bring about droplet ejection.

In another embodiment, all of the heating elements are pulsed with subthreshold electrical pulses, which are insufficient in magnitude to vaporize ink during the standby mode. During the printing mode, those heating elements not being used to eject droplets are pulsed with subthreshold pulses.

A more complete understanding of the present invention can be obtained by considering the following detailed description in conjunction with the accompanying drawings, wherein like parts have the same index numerals.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic, partial isometric view of a typical printhead containing the present invention.

FIG. 2 is a cross sectional view of the printhead of FIG. 1 as viewed along view line 2—2 thereof with control circuitry of the present invention.

FIG. 3 is a schematic isometric view of a typical carriage type multi-color thermal ink jet printer having the printheads of FIG. 1 integrally attached to disposable ink cartridges.

FIG. 4 is a sample plot of an example energy compensating pulse technique to add heat as required to the printheads.

FIG. 5A is a schematic diagram of the control circuitry of FIG. 2.

FIG. 5B is a schematic diagram of an alternate embodiment of the control circuitry of FIG. 5A.

FIG. 6 is a flow chart of the decisions made by the pulse width controller and logic controller of the control circuitry of FIG. 5A.

FIG. 7 is a flow chart of the decisions made by logic complement and logic controller of the control circuitry of FIG. 5B.

FIG. 8A is a partially shown, schematic front view of a pagewidth printhead having a plurality of fully functional subunits mounted on opposite sides of a structural bar.

FIG. 8B is a partially shown, schematic front view of a pagewidth printhead having a plurality of fully functional subunits mounted on the same side of a structural bar.

DESCRIPTION OF THE PREFERRED EMBODIMENT

An enlarged, schematic isometric view of the front face 29 of a typical thermal ink jet printhead 10, showing an array of droplet emitting nozzles 27, is depicted in FIG. 1. Referring also to FIG. 2, discussed later, the lower electrically insulating substrate or heating element plate 28 has the multi-layered, thermal transducers 36, including the heating elements 34, and addressing electrodes 33 patterned on surface 30 thereof, while the upper substrate or channel plate 31 has parallel grooves 20 which extend in one direction and penetrate through the upper substrate front face edge 29. The other end of grooves terminate at slanted wall 21. The internal recess 24, which is used as the ink supply manifold for the capillary filled ink channels 20, has an open bottom 25 for use an an ink fill hole. The surface of the channel plate with the grooves are aligned and bonded to the heater plate 28, so that a respective one of the plurality of heating elements 34 is positioned in each channel, formed by the grooves and the lower substrate or heater plate. Ink enters the manifold formed by the recess 24 and the lower substrate 28 through the fill hole 25 and, by capillary action, fills the channels 20 by flowing through an elongated recess 38 formed in the thick film insulative layer 18. The ink at each nozzle forms a meniscus, the surface tension of which, together with the slight negative pressure of the ink supply, prevents the ink from weeping therefrom. The addressing electrodes 33 on the lower substrate or channel plate 28 terminate at terminals 32. The upper substrate or channel plate 31 is smaller than that of the lower substrate in order that the electrode terminals 32 are exposed and available for wire bonding 15 to the electrodes 14 on the daughter board 19, on which the printhead 10 is permanently mounted. Layer 18 is a thick film passivation layer, discussed later, sandwiched between upper and lower substrates. This layer is etched to expose the heating elements, thus placing them in a pit 26, and is etched to form the elongated recess 38 to enable ink flow between the manifold 24 and the ink channels 20. In addition, the thick film insulative layer is etched to expose the electrode terminals.

A cross sectional view of FIG. 1 is taken along view line 2—2 through one channel and shown as FIG. 2 to show how the ink flows from the manifold 24 and around the end 21 of the groove 20 as depicted by arrow 23. The ink droplets (not shown) are ejected by control circuitry 48, drivers 49, and power supply 52 in

response to receipt of data to be printed. The encoder **50** monitors when the printhead is in the printing region and the optional microprocessor **60** counts the droplet ejecting electrical pulses applied to each of the heating elements **34**. As is disclosed in U.S. Pat. No. 4,638,337 to Torpey et al, a plurality of sets of bubble generating heating elements **34** and their addressing electrodes **33** are patterned on the polished surface of a (100) silicon wafer. Prior to patterning the multiple sets of printhead electrodes **33**, the resistive material **34** that serves as the heating elements, and the common return **35**, the polished surface of the wafer is coated with an underglaze layer **39** such as silicon dioxide, having a thickness of about 2 micrometers. The resistive material may be a doped polycrystalline silicon which may be deposited by chemical vapor deposition (CVD) or any other well known resistive material such as zirconium boride (ZrB_2). The common return and the addressing electrodes are typically aluminum leads deposited on the underglaze and over the edges of the heating elements. The common return ends or terminals **37** and addressing electrode terminals **32** are positioned at predetermined locations to allow clearance for wire bonding to the electrodes **14** of the daughter board **19**, after the channel plate **31** is attached to make a printhead. The common return **35** and the addressing electrodes **33** are deposited to a thickness of 0.5 to 3 micrometers, with the preferred thickness being 1.5 micrometers.

In the preferred embodiment, the lower substrate or heating element plate **28** is silicon with an underglaze layer **39** of thermal oxide or other suitable insulative layer such as silicon dioxide. Polysilicon heating elements **34** are formed and an insulative overglaze layer (not shown) is deposited over the underglaze layer and heating elements thereon. This overglaze layer may be either silicon dioxide, thermal oxide, or reflowed polysilicon glass (PSG). The thermal oxide layer is typically grown to a thickness of 0.5 to 1.0 micrometer to protect and insulate the heating elements from the conductive ink. Reflowed PSG is usually about 2 micrometers thick. The overglaze layer is masked and etched to produce vias therein near the edges of the heating elements for subsequent electrical interface with the aluminum (Al) addressing electrode **33** and Al common return electrode **35**. In addition, the overglaze layer in the bubble generating region of the heating element **34** is concurrently removed. If other resistive material such as hafnium boride or zirconium boride is used for the heating elements, then other suitable well known insulative materials may be used.

The next process step in fabricating the thermal transducer is to deposit a pyrolytic silicon nitride layer **17** directly o the exposed polysilicon heating elements, followed by the deposition of about one micrometer thick tantalum layer **12** for cavitational stress protection of the pyrolytic silicon nitride layer **17**.

The pyrolytic silicon nitride serves two very useful functions. First, it has very good thermal conductivity, so that it produces a thermally efficient resistor structure when deposited directly in contact with the resistor. Secondly, it is one of few materials that is resistant to Ta etches.

The multi-layered, thermal transducer structure is completed with either 4 wt % CVD PSG or preferably, plasma nitride lead passivation. Either of these materials can be selectively etched off the Al bonding pads and resistor area.

For electrode passivation, a two micrometer thick phosphorous doped CVD silicon dioxide film **16** is deposited over the entire heating element plate or wafer surface, including the plurality of sets of heating elements and addressing electrodes. The passivation film **16** provides an ion barrier which will protect the exposed electrodes from the ink. Other ion barriers may be used, such as, for example, polyimide, plasma nitride, as well as the above-mentioned phosphorous doped silicon dioxide, or any combinations thereof. An effective ion barrier layer is achieved when its thickness is between 1000 angstroms and 10 micrometers, with the preferred thickness being 1 micrometers. The passivation film or layer **16** is etched off of the terminal ends of the common return and addressing electrodes for wire bonding later with the daughter board electrodes. This etching of the silicon dioxide film may be by either the wet or dry etching method. Alternatively, the electrode passivation may be accomplished by plasma deposited silicon nitride (Si_3N_4).

Next, a thick film type insulative layer **18** such as, for example, Riston ®, Vacrel ®, Probimer 52 ®, or polyimide, is formed on the passivation layer **16** having a thickness of between 10 and 100 micrometers and preferably in the range of 25 to 50 micrometers. The insulative layer **18** is photolithographically processed to enable etching and removal of those portions of the layer **18** over each heating element (forming recesses **26**), the elongated recess **38** for providing ink passage from the manifold **24** to the ink channels **20**, and over each electrode terminal **32, 37**. The elongated recess **38** is formed by the removal of this portion of the thick film layer **18**.

In thick film layer **18**, the pit **26** is formed having walls **42** that exposes each bubble generating area of the multi-layered thermal transducer **36** and walls **41** defining an elongated recess **38** to open the ink channels to the manifold. The recess walls **42** inhibit lateral movement of each bubble generated by the pulsed heating element which lie at the bottom of recesses **26**, and thus promote bubble growth in a direction normal thereto. Therefore, as disclosed in U.S. Pat. No. 4,638,337, the blowout phenomena of releasing a burst of vaporized ink which causes an ingestion of air is avoided.

The passivated addressing electrodes are exposed to ink along the majority of their length and any pinhole in the normal electrode passivation layer **16** exposes the electrode **33** to electrolysis which would eventually lead to operational failure of the heating element addressed thereby. Accordingly, an added protection of the addressing electrode is obtained by the thick film layer **18**, since the electrodes are passivated by two overlapping layers, passivation layer **16** and a thick film layer **18**.

As disclosed in U.S. Pat. Nos. Re. 32,572 and 4,638,337 and incorporated herein by reference, the channel plate is formed from a (100) silicon wafer to produce a plurality of upper substrates **31** for the printhead. The heating element plate **28** is also obtained from a wafer or wafer sized structure (not shown) containing a plurality thereof. Relatively large rectangular through recesses and a plurality of sets of equally, spaced parallel V-groove recesses are etched in one surface of the wafer (not shown). These recesses will eventually become the ink manifolds **24** and ink channels **20** of the printheads. The channel plate and heating element plate containing wafers are aligned and bonded together, then diced into a plurality of individual printheads. One of the dicing cuts produces end face **29**, opens one end

of the elongated V-groove recesses 20 producing nozzles 27. The other ends of the V-groove recesses 20 remain closed by end 21. However, the alignment and bonding of the above-mentioned wafers places the ends 21 of each set of channels 20 directly over elongated recess 38 in the thick film insulative layer 18 as shown in FIG. 2, enabling the flow of ink into the channels from the manifold 24 as depicted by arrow 23.

The temperature of the improved printhead is held substantially constant, even though it is not ejecting droplets at the extreme ends of the carriage translation. As disclosed in U.S. Pat. No. 4,571,599 to Rezanka and shown in FIG. 3, a typical multicolor thermal ink jet printer 11 is shown containing several disposable ink supply cartridges 22, each with an integrally attached printhead 10 of the present invention. The cartridge and printhead combination are removably mounted on a translatable carriage 40. Curing the printing mode, the carriage reciprocates back and forth on, for example, guide rails 43 parallel to the recording medium 44 as depicted by arrow 45. The end-to-end travel distance of the carriage and printheads is shown as distance B. The recording medium, such as, for example, paper, is held stationary while the carriage is moving in one direction and, prior to the carriage moving in a reverse direction, the paper is stepped in the direction of arrow 46 a distance equal to the height of the swath of data printed thereon by the printheads 10 during traversal in one direction across the paper. The width of the recording medium is the printing zone or region during the carriage traversal and is indicated as distance A. To enable printing by all of the plurality of printheads and to accommodate printhead priming and maintenance stations (not shown), the overall travel distance B is larger than the printing region A. Thus, an encoder 50 (see FIGS. 2 and 5) must be used to monitor when the printheads are within the printing region. The droplets are ejected on demand from the nozzles 27 in front face 29 of the printheads along the trajectories 47 to the paper. The front face of the printhead is spaced from the paper a distance of between 0.01 and 0.1 inch, with the preferred distance being about 0.02 inches. The stepping tolerance for the paper and the linear deviation of the printheads are held within acceptable limits to permit contiguous swaths of information to be printed without gaps or overlaps.

Each cartridge 40 contains a different colored ink, one black and one to three additional cartridges of different selected colors. The combined cartridge and printhead is removed and discarded after the ink supply in the cartridge has been depleted. In this environment, some of the nozzles do not eject droplets during one complete carriage traversal and, generally, none of the nozzles eject droplets as the printheads move beyond the edge of the paper. While at this end of a carriage traversal, there is a small dwell time while the paper is being stepped one swath in height in the direction of arrow 46. Thus, as discussed above, the printhead of the prior art printers cool down. However, the printheads of the present invention are kept at a constant operating temperature by the application of electrical or energy pulses to the heating element not ejecting droplets having insufficient magnitude to vaporize the ink. This supplemental heat keeps the operating temperature of the printhead constant. The number of unused heating elements, the pulse widths, and/or the power of the supplemental pulses control the printhead temperature while it is in the printing mode.

In the preferred embodiment of FIG. 5A, discussed later, a zero data detector 54 enables all heating elements of the printhead to be pulsed with non-droplet ejecting or subthreshold pulses to maintain the operating temperature of the printhead substantially constant. Periodically, the ambient printer temperature is checked by a temperature sensor 55 located within the printer (not shown) and in the vicinity of the printhead 10 for a reference temperature which the logic controller uses to control the compensating energy applied by subthreshold pulses. Optionally, the temperature of the printhead could be used instead of the ambient printer temperature. This reference temperature is checked at startup, when entering the printing mode, and at the conclusion of printing a predetermined number of full pages, rather than sensing the printhead temperature continually or frequently such as during or after each swath of printed information as required by the prior art. Thus, this invention does not need to continually check the printhead temperature or even check for a reference temperature more frequently than after printing more than one page. A pulse count look up table 51 in response to the pulse counter 61, which counts the droplet ejecting pulses required by the data to be printed, determines the umber and width of the non-droplet ejecting (subthreshold) pulses in conjunction with the subthreshold pulse width controller 56 and enables the logic controller to apply the required subthreshold pulses having the appropriate pulse width to the heating elements not ejecting droplets.

Optionally, a microprocessor 60 counts the droplet ejecting pulses per heating element per unit of time, so that if the number of heating elements used and/or the rate of droplets expelled are not within predetermined values, supplemental heat is applied to the printhead by subthreshold pulsing of the least used heating elements. Subthreshold pulses are not capable of vaporizing the ink, so that droplets are not ejected. A consequence of using supplemental heat to keep the temperature of the printhead constant during printing is that the average device temperature will be higher than it would be otherwise. However, this is an advantage, if the temperature is kept below a predetermined maximum temperature, whereat the printhead begins to fail. This maximum temperature is about 70° C. when the inks used comprise ethylene glycol and a water base, but varies with different ink formulations and ink channel geometries. Below 70° C., the drop velocity becomes more uniform as the temperature is increased. At 20° C., some ink channels of the printhead having water based ink formulations have been observed to have marginally acceptable droplet velocities. The droplet velocity increases to a highly satisfactory range with a moderate increase in printhead temperature. The ideal operating point depends on ink and device parameters, but in the present case would appear to be roughly 30° C. to 50° C. An additional advantage of operating at elevated temperature is that the ink viscosity decreases, so that refill times of the channels may be decreased, enabling higher printing frequencies. The printhead 10 has a heat sink 71 with a predetermined heat dissipating capacity, so that the heat added to the printhead by the droplet ejecting pulses and the subthreshold pulses will be dissipated at a known rate and taken into account by the pulse count look up table 51 and/or the optional microprocessor 60.

In FIG. 4, one embodiment of this invention is shown in which, for example, a 48 jet or channel printhead is

used, printing up to two channels at a time. In this example of an energy compensating pulse scheme, the 48 channels are being pulsed 2 at a time and channels 1, 2, 3, 24, 25, 26 and 48 are assumed to have printed. The shorter pulses during the compensation cycle are provided so that the total energy dissipated in the time interval associated with a group of 48 pixels is constant. Since the carriage is moving continuously, it is necessary to finish printing all 48 jets in a fraction of the time it takes to get from one pixel to the next, or the dot or pixel pattern will be too jagged. AT 2 kHz operation, we have 500 μsec to get from one pixel position to the next, while at 3 kHz, we would have 333 μsec. By comparison, the printing cycle is composed of 24 intervals of 5 μsec (120 μsec total), during which up to two channels will be fired or energized at a time using about 3 μsec duration pulses. The energy dissipated during the printing cycle in one set of up to 48 pixels is $E_p = n\ P\ t_p$, where n is the number of channels fired (0 to 48), P is the power per print pulse, and t_p is the pulse width (3μsec in our example). The maximum energy dissipated is $E_{max} = NP\ t_p$, where N=48 in our example. For strictly constant energy input, m short pulses would be added (none of which is sufficient for bubble nucleation) during what is normally a "rest period", so that $E_p + E_c = n\ P\ t_p + m\ P\ t_c = E_{max} = N\ P\ t_p$, where E_c is the compensating energy and t_c is the pulse width or duration of the compensating pulse. For example, if $t_c = t_t/4$ (0.75 μsec), then n+m/4=48, and during period s of time when printing is not occurring (n=0), there would be 192 of the short pulses required. For 2 kHz operation the energy compensating cycle would be 350 μsec (allowing 120 μsec printing cycle and 30 μsec setup times). By pulsing up to 2 heaters at a time during the energy compensating cycle, as would be done during the printing cycle, there will be 96 pulse intervals, so that the short pulses would be on for 0.75 μsec and off for 2.9 psec. Other cases of interest are shown in Table 1, assuming 120 μsec printing cycle and 30 μsec setup times. Selection criteria are that bubbles not be nucleated during t_c, but that the driver transistors be fast enough.

TABLE 1

	Energy Compensating Pulse Widths (μsec)		
t_p/t_c	t on	2 kHz t off	3 kHz t off
4	.75	2.9	1.2
3	1.0	3.9	1.5
2	1.5	5.8	2.3

A variety of method or embodiments may be devised for implementing the logic for the energy compensation pulses. One method would be to count the pulses during the printing cycle and decrement a counter for the compensation cycle accordingly. Referring to FIG. 5A, this method does not keep track of which heating elements were fired, unless the optional microprocessor 60 is used, and would simply cycle through the heating elements not being used to eject droplets until enough compensating pulses were fired. The pulse counter 61, zero data detector 54 and logic controller 58 of the control circuitry 48 receive data to be printed in the form of digitized data signals. The encoder 50 provides signals indicative of the location of the printhead 10, relative to the printing region A of FIG. 3, to the logic controller 58 and subthreshold pulse width controller 56. The pulse counter 61 determines how many jet or heating elements are being fired during a particular time interval. Jets fired have a pulse width given by the ejection pulse controller 62. In the event that the zero data detector 54 indicates that no jets are to be fired (i.e., no droplets are to be ejected as when a new page of printing has not begun, or the printhead has reached the end of a line, or during white space within a line), it indicates to the logic controller 58 that subthreshold pulse firing may occur. The pulse count look up table 51 compares the number of droplet ejection pulses which have recently been first or are about to be fired, and indicates to the subthreshold pulse width controller 56 how many and how wide the subthreshold pulses should be to bring the printhead 10 to the desired operating point.

In the preferred embodiment, the power supply 52 provides a constant voltage V_o to the common return electrode 35. The heating elements 34 are pulsed with this voltage through drivers 49 which are connected to the printhead addressing electrodes 33 and to ground. Thus, the electrical pulses applied to the heating elements or resistors 34 have a constant amplitude and the width is varied to eject a droplet or provide only supplemental heat with pulse widths insufficient to vaporize ink. Clock 53 provides the timing for the logic controller 58. The control circuitry 48 may optionally contain a look up table 57 (shown in dashed line) which receives input signals representative of the ambient temperature from temperature sensor 55 located within the printer (not shown) in the vicinity of the printhead or optionally thereon. Based upon the temperature sensor, the subthreshold pulse width controller signals the logic controller for supplemental heat generating electrical pulses insufficient to eject droplets.

An optional dedicated heater 59 on the printer, but not shown in FIG. 2, could also be used to provide the required supplemental heat to the printhead instead of pulsing the heating elements, as is well known in the art.

An optional microprocessor 60 keeps track of which heating elements have not been fired very often and employs those heating elements which have not been used often to do the threshold pulsing, in order to average out the overall number of pulses for each heating element for lifetime purposes. This is accomplished by counting the number of droplet-ejecting pulses each heating element received during a predetermined time period, such as, for example, during the printing of a swath of information. This count per heating element could be stored and averaged or simply erased after each printed swath or printed page.

Alternately, as shown in FIG. 5B, a device 63 for determining the logical complement of the printing data is given to the subthreshold pulse width controller 67 so that those heating elements which are not fired to eject droplets are automatically pulsed with subthreshold pulses. This ensures that each heating element experiences the same number of pulses for lifetime purposes, although some experience a greater number of droplet ejection pulses.

The decisions made by the pulse width controller 56 in the control circuitry 48 of FIG. 5A is shown in the flow chart of FIG. 6. When the printing mode is activated, the ink channels are primed and the heating elements are all pulsed with electrical current pulses having sufficient magnitude or average power to vaporize the ink in contact therewith and eject nozzle clearing droplets in an ink collection recess or absorbent material forming part of a maintenance station (not shown). After a predetermined number of droplets are ejected from each nozzle, the printhead warmup is continued

with application of subthreshold electrical pulses to the heating elements. By subthreshold, it is meant those pulses having insufficient energy or average power to vaporize ink and expel ink droplets.

Upon receipt of digitized data to be printed, the location of the printhead is checked to see if it is within the printing region A as shown in FIG. 3. If not, the printhead is pulsed with subthreshold pulses to provide supplemental heating while it is moved into proper position for printing. Once the printhead is in the printing region, droplets are ejected and propelled to a recording medium 44. The pulse counter 61 counts the number of pulses which eject droplets and the logic controller 58 determines the pulses per clock time unit, that is the printing rate or density, and compares this rate or density with a minimum value required to maintain the operating temperature of the printhead within the appropriate temperature range.

Optionally, the microprocessor 60 identifies which nozzles were fired; i.e. used to expel droplets. If the printing density is sufficient to maintain the printhead operating temperature sufficiently constant, printing is continued without supplemental heating. If not, the number and width of subthreshold pulses required are determined by the logic controller and those heating elements not being used to eject droplets are pulsed with the subthreshold pulse. If desired, the subthreshold pulses can be applied only to those heating elements which have not ejected a droplet during the time period for which the droplet rate or density was measured. For example, at intermediate points along a swath of printed droplets or at the end of a printed swath or both.

Thus, the operating temperature of the printhead of the present invention is maintained substantially constant within the appropriate temperature without the need for continually measuring the printhead temperature and modifying the printing speed to cool it down or add heat to boost the temperature until the printhead sensor reads the desired value.

A temperature sensor 55 within the printer is used periodically during standby or initial start-up of printing, but constant reference to it is not required. The decisions made by the control circuitry 48A of FIG. 5B are shown in the flow chart of FIG. 7. AS in the flow chart of FIG. 6, the ink channels are primed and the heating elements pulsed to eject nozzle clearing droplets when the printing mode is activated. After a predetermined number of droplets are ejected from each nozzle, the printhead warmup is continued with the application of subthreshold pulses to the heating elements.

Upon receipt of data to be printed, the location of the printhead is checked to see if it is within the printing region by the encoder 50. If not, the printhead is pulsed with subthreshold pulses to provide supplemental heating while it is being moved into the proper position for printing. Once the printhead is in the printing region, droplets are ejected and propelled to the recording medium 44. The logical complement 63 identifies those heating elements not being used to eject droplets, and in response to the logical complement input, the subthreshold pulse width controller 67 and ejection pulse controller 62 via logic controller 58 apply respective pulses to each heating element. In this arrangement all of the heating elements are fired or pulsed with either droplet ejecting pulses or subthreshold pulses during the actual printing operation. Thus, when no data is to be printed, only subthreshold pulses are applied to the heating elements. The subthreshold pulse width is determined by the ambient temperature sensor 55 and the known heat transfer rate from the heat sink 71.

This invention does not restrict itself to the case of $E_p+E_c=E_{max}$. For one thing, E_c should probably be somewhat less than $E_{max}-E_p$ because no heat is being carried off by ejected drops during the compensation cycle. In addition, it is not necessary to keep the printhead temperature exactly constant. It may be found that an upper limit of compensation less than E_{max} is satisfactory. The advantage of using less energy compensation is that it would be easier to maintain a thermal equilibrium which did not approach the upper operating temperature for a longer period of time.

Energy compensation will be required whenever printing is occurring or about to occur. In particular, energy compensation should continue at its maximum rate during carriage pauses at the end of travel. It should also occur just preceding starting to print. Warmup time should not be objectionably long, but in a one page per minute printer 1-4 seconds should be satisfactory for a large part of the temperature rise occurs within 3 seconds. The heat sinking should be designed so that the device temperature is raised for the most part within a few seconds, and then rises much slower after that. Energy compensation could also be applied for the longer term heating effects, e.g., by decrementing a counter a certain number of pulses for each line printed. The other heat sink requirement is that the device temperature remain in the optimal range (e.g., 40° C. ±10° C.).

Energy compensation may also be controlled by modifying the pulse width, t_c, depending on the number of channels fired during the printing cycle. In one embodiment, short compensating pulses are fired only during the compensation cycle. In another embodiment, short pulses are fired during the printing cycle as well, with the pulse width widened for those channels where printing is desired. The minimum pulse width increment would be determined by the fastest clock in the system, which might typically be 10-20 MHz. Another way to control the energy compensation is to modify its pulse power, but this is more difficult to implement. It has been assumed here that the compensation energy is provided by the same heating elements responsible for printing, but this is not a requirement. One or more special heating elements (not shown) for supplying only supplemental heat may be formed anywhere on the heating element plate 28, preferably in a location where they do not contact the ink.

The advantages of this inventive compensating pulsing scheme are as follows:

1. It may be implemented without temperature sensors or extra heating elements being on the printhead.

2. It is capable of making thermally induced spot size variation and banding negligible.

3. Thermal packaging to obtain a lower thermal resistance path from device to heat sink becomes less critical.

4. Peak power required for bubble formation is reduced, since spot size increases with device temperature as well as print pulse condition.

5. Operation at elevated temperature will improve uniformity of drop velocity, thus improving the yield of good performing devices.

6. Operation at elevated temperature is expected to decrease ink viscosity within the device, and improve channel refill times.

An additional feature that might prove useful is a temperature sensor on the printhead that measures the absolute temperature. The energy compensation scheme could then be modified, for example, through the use of lookup tables to provide the desired device temperature independent of ambient temperature or length of time the printer has been operating.

Although the above description was cast in terms a carriage type ink jet printer, this invention is equally applicable to a page width or partial page printer. The subthreshold pulses would keep all of the subunits or modules making up the page width printhead at the same temperature, so that they would produce droplets having the same volume and the printed spot size would be uniform. By applying subthreshold temperature compensating pulses in relation to the density of printing by each module, they all could be maintained within the desired operating temperature without the need of individual temperature sensors on each printhead subunits, but only one within the pagewidth printhead structural bar.

In one embodiment, a printhead is composed of a plurality of fully functional, small individual printhead subunits. Each subunit could be used individually as a carriage type printhead capable of being scanned across a recording medium to print a swath of pixels or dots of ink. Referring to FIGS. 8A and 8B, a plurality of the printhead subunits **66** are mounted on a structural bar **68** which could either be translated across a recording medium, (not shown) to print partial pages (e.g., one large swath of information) or be fixed for page width printing where the recording medium is moved thereby at a constant velocity. In FIG. 8A, the subunits are alternately mounted on opposite sides of the bar with spaces between subunits on the same side of the bar. A single temperature sensor **69** mounted on the bar is used to establish a reference temperature for determining the number and/or width of the subthreshold pulses applied to the heating elements of each printhead subunit **66**. The control circuitry **48C** or **48D** either uses the logic complement (not shown) of the data to be printed to apply subthreshold pulses (those pulses having a magnitude insufficient to vaporize ink) to all heating elements in each subunit not ejecting droplets or counts the droplet ejecting pulses and through a lookup table determines the number and pulse width of the subthreshold pulses of predetermined heating elements not ejecting droplets. A microprocessor **60B** could be optionally used to count the number of droplets ejected by each heating element in each subunit and apply subthreshold pulses to the heating elements least used to eject droplets. The droplet ejecting or subthreshold pulses are applied by the control circuitry via the drivers **49**. The temperature sensor provides a reference temperature of the structural bar **68** or ambient temperature which is only used at startup and then periodically, but infrequently, as a reference parameter. The primary control of the operating temperature is by monitoring the heat energy applied to the printhead subunits in the form of droplet ejecting or subthreshold pulses per unit of time after the reference or ambient temperature has been established. Thus the desired operating temperature of each subunit is maintained within the same desired operating temperature without the need of individual temperature sensors on each printhead subunit.

Many modifications and variations are apparent from the forgoing description of the invention, and all such modifications and variations are intended to be within the scope of the present invention.

We claim:

1. A method of maintaining the operating temperature of a thermal ink jet printhead substantially constant while it is in a printing mode and ejecting ink droplets from a plurality of nozzles therein, comprising the steps of:

counting a number of ink droplet ejecting electrical pulses applied to heating elements within the printhead that effect the ejection of ink droplets form the printhead nozzles during predetermined time periods;

comparing the counted number of said droplet ejecting pulses per predetermined time period with a minimum number required per predetermined time period to maintain the desired operating temperature constant and determining a number of droplet ejecting pulses which is less than said minimum number; and

pulsing predetermined heating elements not being used to eject droplets with electrical pulses insufficient in magnitude to vaporize ink when the number of droplet ejecting pulses are less than said minimum number to provide supplemental heat to the printhead which is equivalent to heat that would have been added by said determined number of droplet ejecting pulses which are less than said minimum number, so that the printhead is maintained at a substantially constant operating temperature, while the printhead is in the printing mode, without the need of continually sensing the printhead temperature.

2. The method of claim **1**, wherein the method further comprises the step of identifying the heating elements used to eject droplets during said predetermined time period, in addition to the counting of the droplet ejecting electrical pulses, and determining those heating elements infrequently used to eject droplets; and

wherein said predetermined heating elements pulsed with electrical pulses insufficient in magnitude to vaporize ink are those heating elements determined to be infrequently used to eject droplets during said printing by the printhead.

3. The method of claim **1**, wherein the method further comprises the step of determining a number and a width of each of the electrical pulses insufficient in magnitude to vaporize ink which are to be used to pulse said predetermined heating elements.

4. The method of claim **4**, wherein the width of the electrical pulses insufficient in magnitude to vaporize ink is established so that the predetermined heating elements pulsed therewith are all heating elements not ejecting droplets.

5. The method of claim **4**, wherein the method further comprises the steps of providing a heat sink for the printhead with a known heat dissipating capacity; and periodically establishing an ambient temperature of a location within the vicinity of the printhead to establish a reference parameter which is used in conjunction with the counted droplet ejecting electrical pulses to determine the number and width of the electrical pulses insufficient in magnitude to vaporize ink without the need to continually check the printhead temperature or estimate thereof.

6. An improved thermal ink jet printhead of the type having an ink supply manifold, a plurality of capillary-filled, parallel ink channels that communicate at one end

with the manifold and terminate at the other end with a nozzle, and a linear array of heating elements, one located in each ink channel, the printhead ejecting ink droplets on demand by the selective energization of the heating elements with electrical energy pulses having sufficient magnitude to vaporize instantaneously the ink in contact with the energized heating element, so that temporary vapor bubbles are formed which eject said ink droplets, wherein the improvement comprises:

means for counting a number of electrical energy pulses which ejected ink droplets during predetermined time periods;

means for comparing the counted number of electrical energy pulses which ejected ink droplets during said predetermined time periods with a minimum number of such pulses that are required to maintain the printhead operating temperature substantially constant; and

energization of predetermined heating elements with electrical energy pulses insufficient i magnitude to vaporize the ink at times when said predetermined heating elements are not being energized for the ejection of ink droplets but concurrently when other heating elements are ejecting ink droplets to provide supplemental heat to the printhead, whenever the minimum number of droplet ejecting pulses is not met, so that the printhead is maintained at a substantially constant operating temperature while the printhead is in a printing mode without the need for continually sensing the printhead temperature.

7. The printhead of claim 6, wherein the printhead further comprises means for identifying the heating elements used to eject droplets during said predetermined time period and determining the heating elements most infrequently used.

8. The printhead of claim 7, wherein the printhead further comprises means for determining a number and a width of the energy pulses which are insufficient in magnitude to vaporize the ink; and wherein the heating elements determined to be most infrequently used to eject droplets are pulsed with the determined number of energy pulses with the determined pulses widths, which are each insufficient in magnitude to vaporize ink, so that the heating elements are pulsed more equally to provide more predictable heating element lifetimes.

9. The printhead of claim 6, wherein the predetermined heating elements are all heating elements not ejecting droplets are pulsed with energy pulses insufficient in magnitude to vaporize the ink to provide supplementary heat to the printhead.

10. The printhead of claim 9, wherein an ambient temperature in the vicinity of the printhead is periodically sensed to establish a reference parameter from which a number and w width of energy pulses insufficient in magnitude to vaporize the ink are established.

11. The printhead of claim 10, wherein said periodic sensing of the ambient temperature is done at a time when the printhead enters a printing mode and again after the printing of each page of information by the printhead.

12. A thermal ink jet printhead for use in an ink jet printer and of the type having a plurality of fully functional printhead subunits mounted on a structural bar, each printhead subunit having a linear array of equally spaced nozzles and a heating element for each nozzle, the printhead subunits being equally spaced from a recording medium and adapted to eject ink droplets on demand from selected nozzles in response to electrical energy pulses representative of data to be printed, which are applied to the heating elements of each printhead subunit, comprising:

means for counting a number of droplet ejecting electrical energy pulses applied to the heating elements of each respective subunit which ejects ink droplets from nozzles therein during predetermined time periods;

means for comparing each of the counted number of electrical energy pulses which ejected ink droplets during said predetermined time periods with a minimum number of such pulses that are required to maintain each printhead subunit operating temperature substantially constant and determining a number of droplet ejecting electrical energy pulses which are less than said minimum number of such pulses; and

energization of predetermined heating elements in each printhead subunit not being used to eject droplets with subthreshold energy pulses insufficient in magnitude to vaporize ink to provide supplemental heat to the printhead subunits which is equivalent to heat that would have been added by said determined number of droplet ejecting electrical energy pulses which are less than said minimum number, in order to maintain all of the printhead subunits within the desired operating temperature.

13. The printhead of claim 12, wherein the printhead further comprises:

means for periodically sensing the temperature of the structural bar, so that a reference temperature may be determined for use in determining the predetermined heating elements in each printhead which shall have subthreshold energy pulses applied thereto without the need of individual temperature sensors on each printhead subunit.

14. The pagewidth printhead of claim 13, wherein the means for periodically sensing the temperature of the structural bar is via a temperature sensor mounted thereon, the periodic sensing being accomplished at start of printing and after each page of printing is completed on a page of recording medium.

15. The printhead of claim 13, wherein the printhead contains a quantity of printhead subunits mounted along the structural bar sufficient to produce a pagewidth printhead capable of printing at least one line of pixels across the width of one page.

16. The printhead of claim 15, wherein the pagewidth printhead is fixed and the recording medium is moved thereby at a constant velocity.

17. The printhead of claim 16, wherein the pagewidth printhead further comprises means for determining the quantity and pulse width of the subthreshold pulses.

18. The printhead of claim 16, wherein all of the heating elements of each subunit are pulsed with either a droplet ejecting pulse or a subthreshold pulse for supplemental heating during the printing mode.

19. A method of maintaining a desired operating temperature of a printhead in a thermal ink jet printer substantially constant, the printhead having a plurality of nozzles and a heating element for each nozzle, and the printer having a controller for selectively applying either droplet ejecting or non-droplet ejecting electrical pulses to the printhead heating elements, so that, when the printhead is in a printing mode, the printhead is capable of ejecting ink droplets from the nozzles having satisfactory velocities in response to droplet ejecting

electrical pulses applied to selected heating elements, comprising the steps of:

(a) providing a heat sink for the printhead having a known rate of heat dissipation to remove heat continually from the printhead;

(b) counting droplet ejecting electrical pulses applied to the printhead heating elements during a predetermined time period, each droplet ejecting electrical pulse adding a first known amount of heat energy to said printhead;

(c) comparing the counted droplet ejecting electrical pulses with a minimum number thereof required to maintain the desired printhead operating temperature constant, while said heat sink is dissipating heat, and deriving a number of such pulses which are less than said required minimum number;

(d) determining a number of non-droplet ejecting pulses required to maintain the desired operating temperature of the printhead, when the counted droplet ejecting pulses are less than the minimum number required, each non-droplet ejecting pulse adding a second known amount of heat energy to the printhead; and

(e) applying said determined number of non-droplet ejecting pulses to the printhead heating elements in nozzles not being used to eject droplets, so that the printhead is maintained at a substantially constant operating temperature without the need of continually sensing the printhead temperature.

20. The method of claim **19**, wherein the determined number of non-droplet ejecting pulses applied to the printhead heating elements during step (e) are applied to all heating elements not being used to eject droplets, so that each heating element is being pulsed with either a droplet ejecting pulse or a non-droplet ejecting pulse.

21. The method of claim **19**, wherein the determined number of non-droplet ejecting pulses applied to the printhead heating elements during step (ea) are applied to predetermined heating elements not being used to eject droplets.

22. The method of claim **21**, wherein the method further comprises the steps of:

(f) identifying the heating elements in step (b) which are used to eject droplets and generating a signal indicative thereof;

(g) averaging the use of each of said identified heating elements;

(h) storing the signal indicative of the identified heating elements and their average use in a data base; and

(i) using the data base to select the least used heating elements for application of the non-droplet ejecting pulses in step (e) in order to average out the overall number pulses of per heating element to increase the life time of the printhead.

23. The method of claim **21**, wherein the method further comprises the step of: periodically sensing a temperature of a location within the vicinity of but spaced from the printhead to establish a reference parameter for use by the controller at predetermined periodic time's to establish, in conjunction with the known rate of heat dissipating of said heating sink, the pulse widths of the non-droplet ejecting pulses.

* * * * *

US005812156A

United States Patent [19]

Bullock et al.

[11] **Patent Number: 5,812,156**

[45] **Date of Patent: Sep. 22, 1998**

[54] **APPARATUS CONTROLLED BY DATA FROM CONSUMABLE PARTS WITH INCORPORATED MEMORY DEVICES**

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[73] Assignee: **Hewlett-Packard Company**, Palo Alto, Calif.

[21] Appl. No.: **785,580**

[22] Filed: **Jan. 21, 1997**

[51] **Int. Cl.**[6] **B41J 29/393**

[52] **U.S. Cl.** **347/19**; 347/14

[58] **Field of Search** 347/17, 14, 7, 347/19

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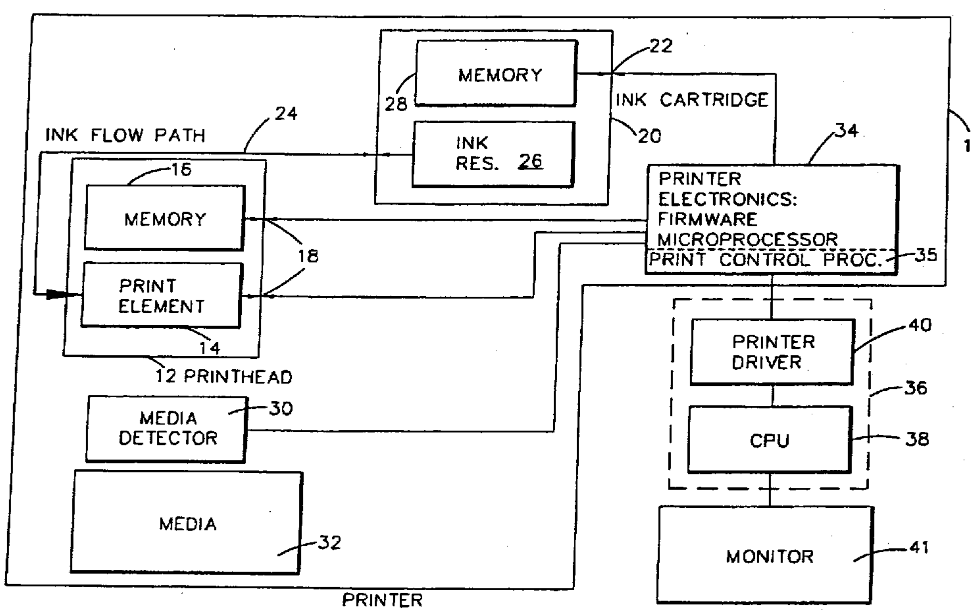
Primary Examiner—Edgar S. Burr
Assistant Examiner—Dave A. Ghatt

[57] **ABSTRACT**

A printing system includes a replaceable cartridge for housing a supply of consumable marking media. The cartridge includes a cartridge memory for recording printing system-related parameters, including marking media parameters. A replaceable printing device, such as an ink jet head, includes a printhead memory for recording printing device-related parameters. A processor is coupled to the cartridge memory, the printhead memory and is responsive to parameters read from both memories to derive printing system function control values that are dependent upon one or more marking media parameters from the cartridge memory and one or more parameters from the printhead memory. The processor is thus able (in the case of an ink jet printing system) to determine a current ink supply value from a cumulative usage value stored on the cartridge memory and a drop volume parameter stored on the printhead memory. Further, a drop volume parameter stored on the printhead memory can be adjusted to accommodate a media type sensed by a media sensor.

24 Claims, 5 Drawing Sheets



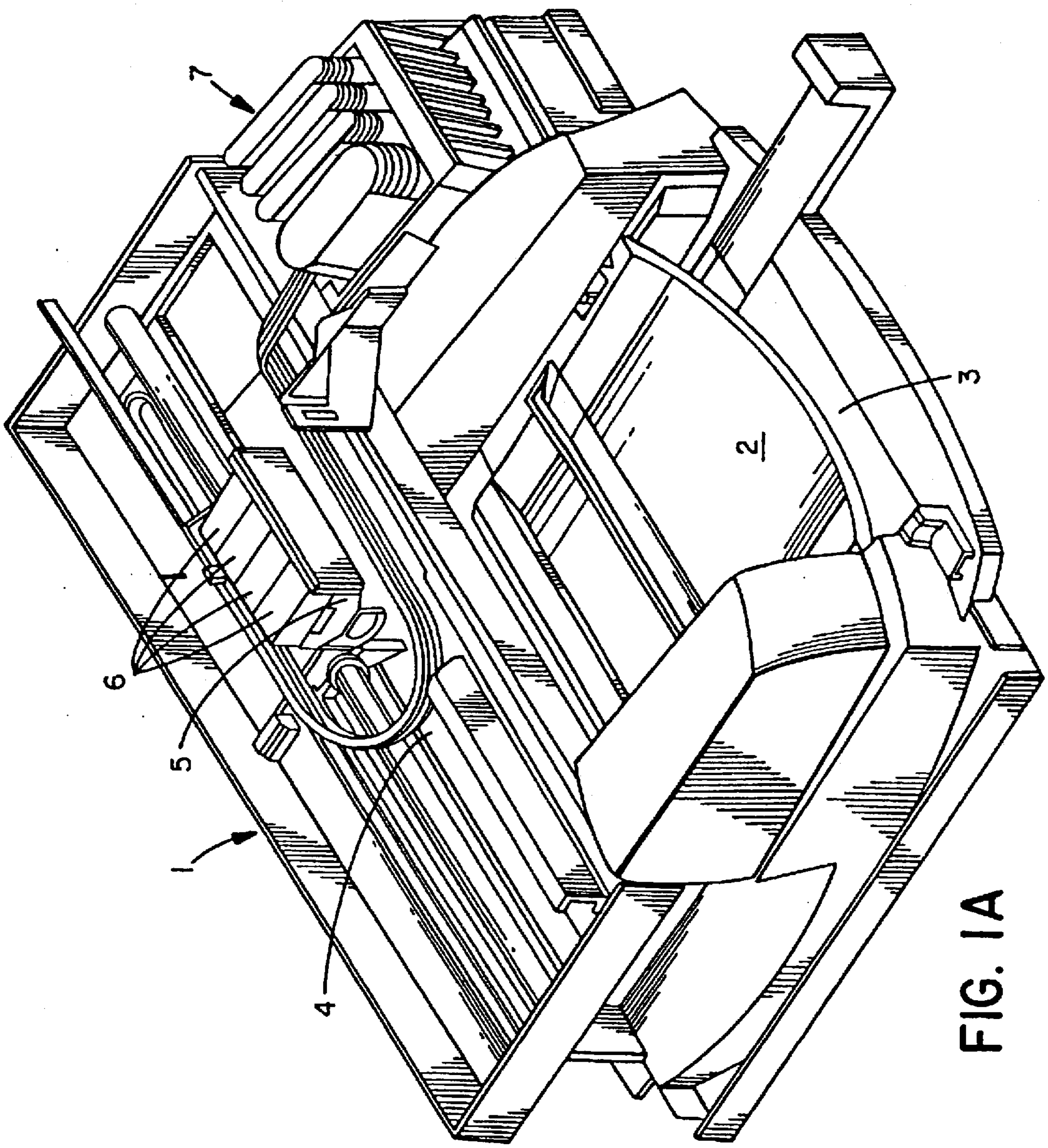
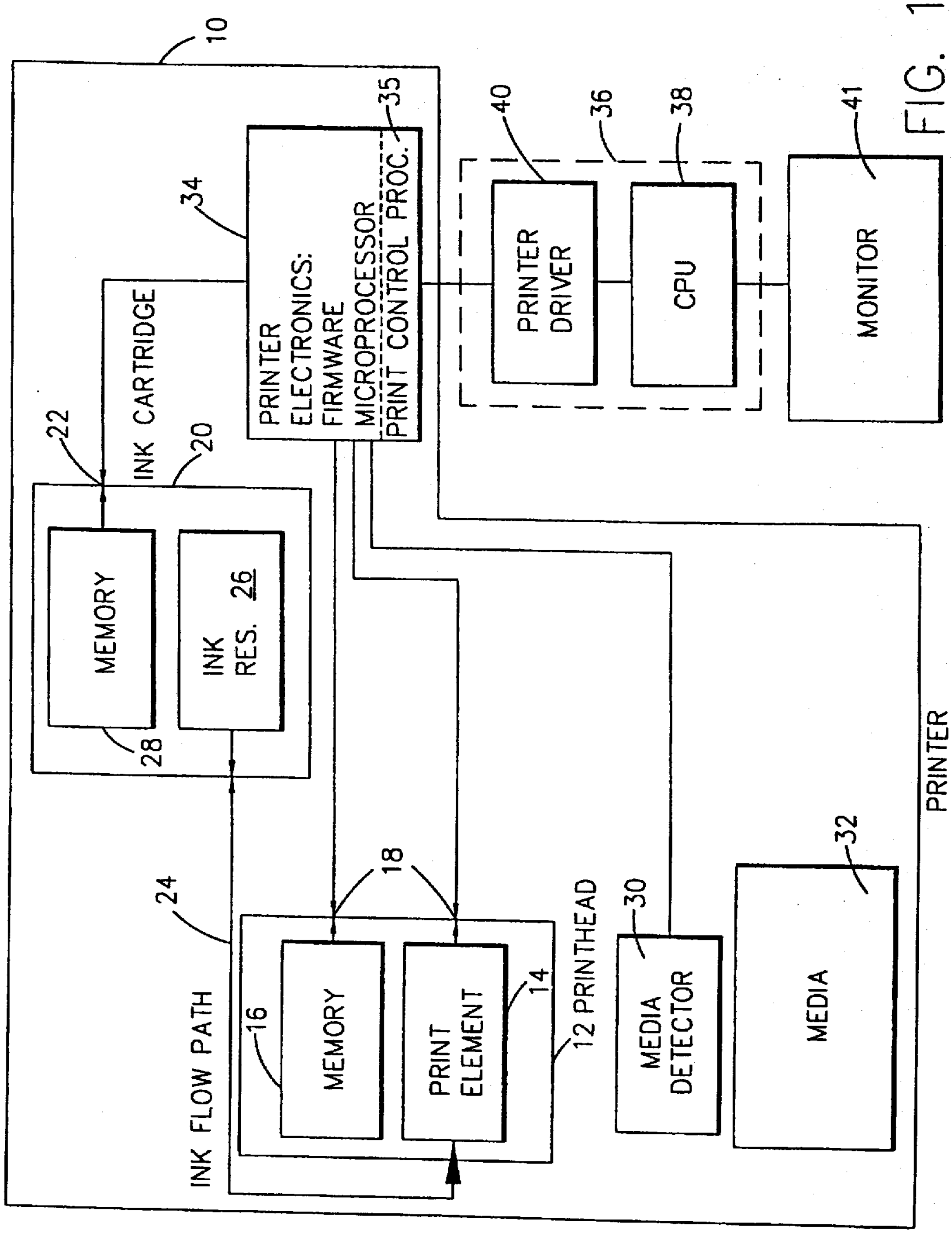


FIG. 1A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PRINTER ELECTRONICS: FIRMWARE MICROPROCESSOR
PRINT CONTROL PROC.
35
34
40
36
38
PRINTER DRIVER
CPU
41
MONITOR
INK CARTRIDGE
22
20
MEMORY
28
INK RES. 26
24
INK FLOW PATH
18
MEMORY
16
PRINT ELEMENT
14
12 PRINTHEAD
30
MEDIA DETECTOR
32
MEDIA
PRINTER

FIG. 1B

FIG. 3

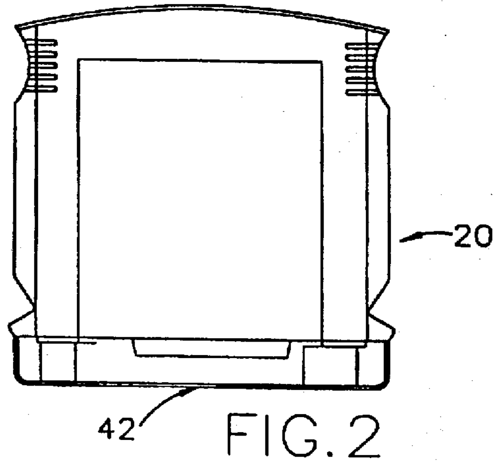


FIG. 2

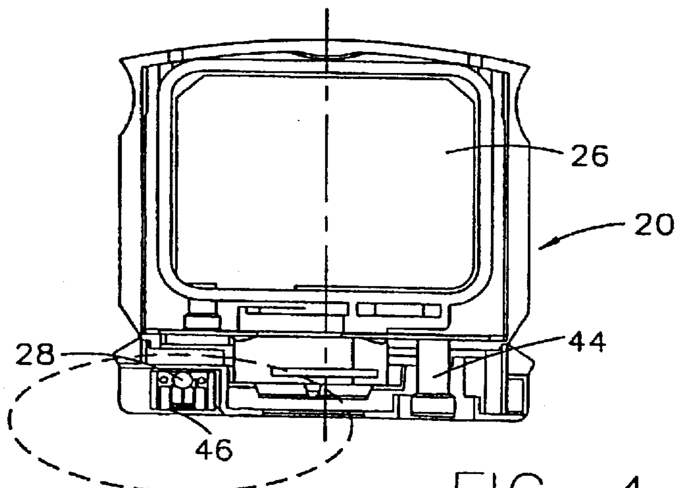


FIG. 4

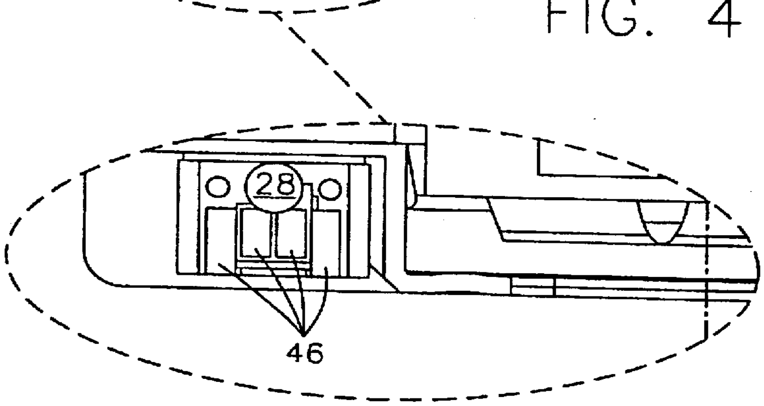


FIG. 4A

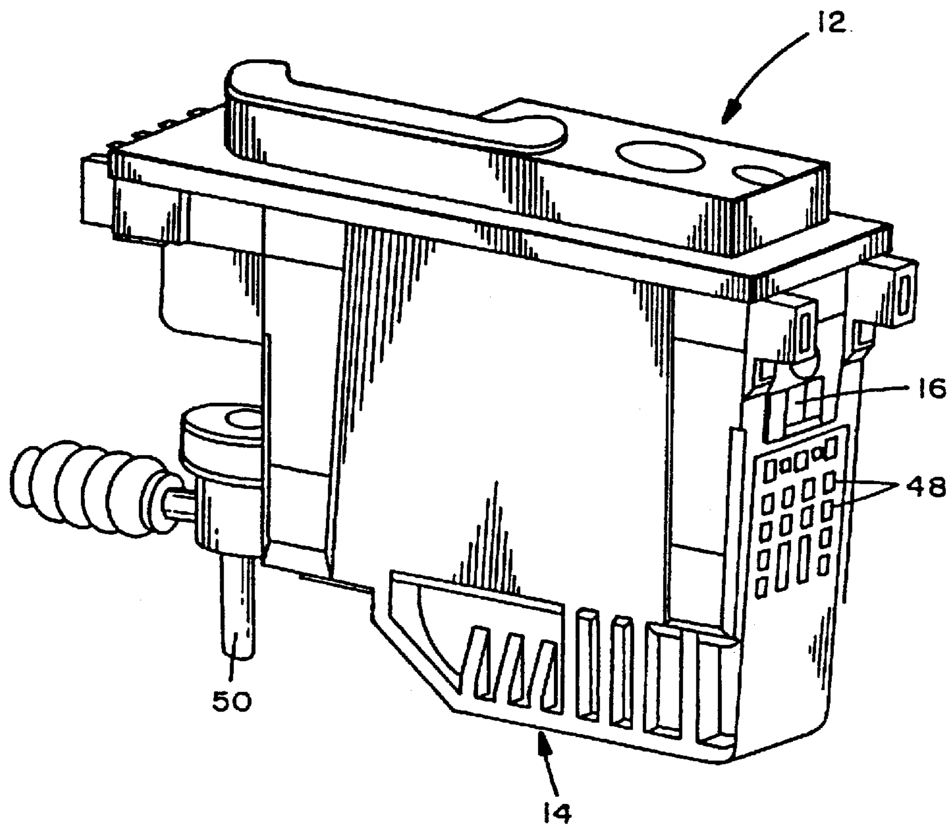
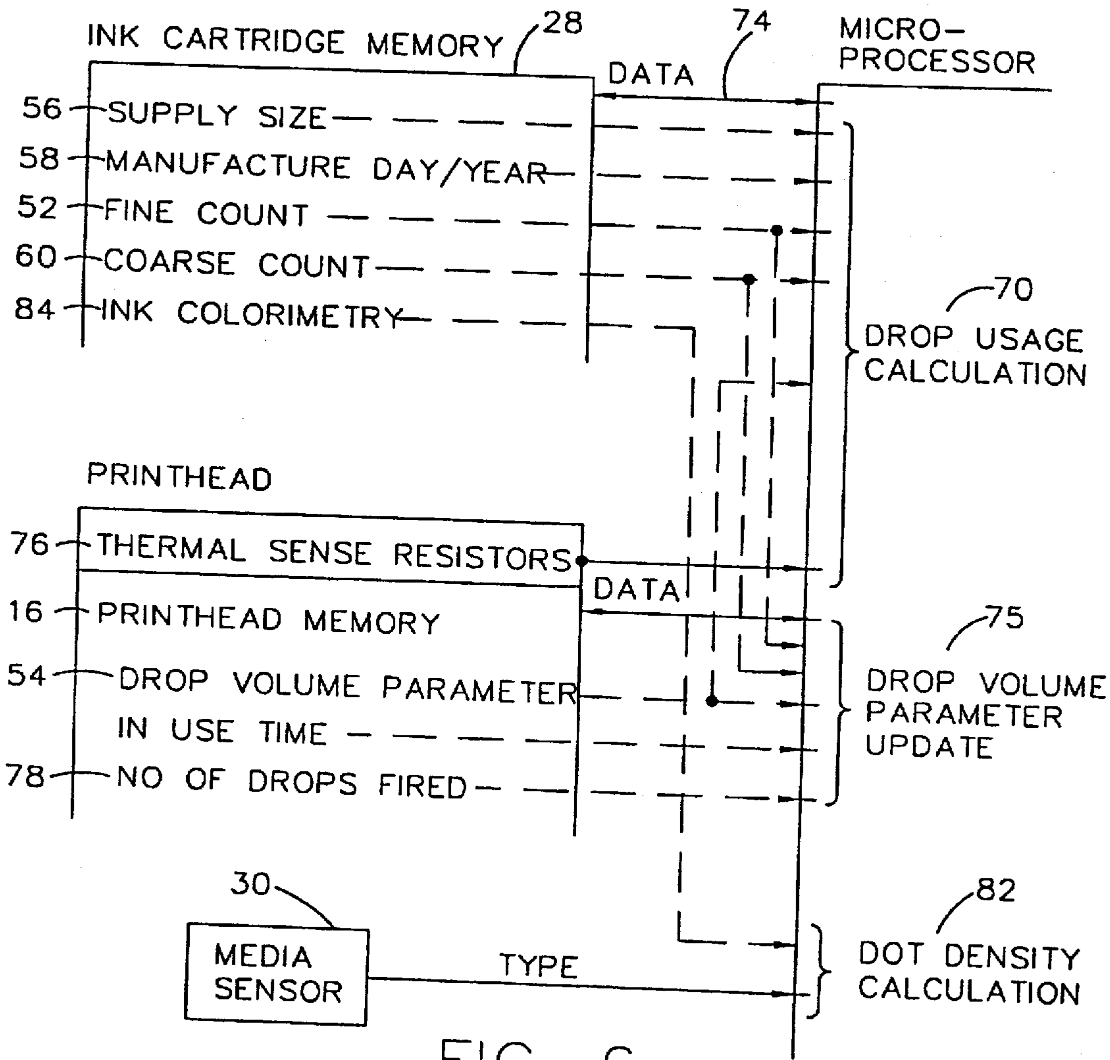


FIG. 5


INK CARTRIDGE MEMORY
28
74
DATA
MICRO-
PROCESSOR
56
SUPPLY SIZE
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MANUFACTURE DAY/YEAR
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FINE COUNT
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COARSE COUNT
84
INK COLORIMETRY
70
DROP USAGE
CALCULATION
PRINTHEAD
76
THERMAL SENSE RESISTORS
DATA
16
PRINTHEAD MEMORY
54
DROP VOLUME PARAMETER
IN USE TIME
78
NO OF DROPS FIRED
75
DROP VOLUME
PARAMETER
UPDATE
30
MEDIA
SENSOR
TYPE
82
DOT DENSITY
CALCULATION

FIG. 6

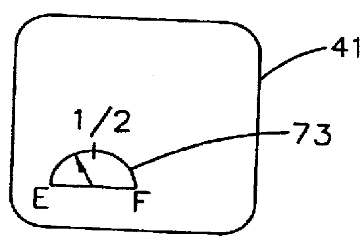
41
1/2
73
E
F

FIG. 7

APPARATUS CONTROLLED BY DATA FROM CONSUMABLE PARTS WITH INCORPORATED MEMORY DEVICES

FIELD OF THE INVENTION

This invention relates to apparatus that employs replaceable, consumable parts and, more particularly, to consumable parts which include integral memory for storing usage, calibration and other data that is used by a controlling processor to operate the apparatus.

BACKGROUND OF THE INVENTION

Substantially, all present-day copiers, printers, plotters, etc., include a controlling microprocessor which requires input calibration data to assure high quality production of documents. Since most such apparatus allows user-replacement of consumable items, various techniques have been developed to enable entry of usage, calibration and other data.

In regards to ink jet printers, it has been proposed that print heads incorporate a parameter memory for storage of operating parameters such as: drop generator driver frequency, ink pressure and drop charging values (see "Storage of Operating Parameters in Memory Integral with Print Head", Lonis, Xerox Disclosure Journal, Volume 8, No. 6, November/December 1983, page 503). U.S. Pat. No. 5,138,344 to Ujita, entitled "Ink Jet Apparatus and Ink Jet Cartridge Therefor", indicates that an ink-containing replaceable cartridge can be provided with an integral information device (i.e., a resistor element, magnetic medium, bar code, integrated circuit or ROM), for storage of information relating to control parameters for the ink jet printer.

U.S. Pat. No. 5,365,312 to Hillmann et al., entitled "Arrangement for Printer Equipment Monitoring Reservoirs that Contain Printing Medium", describes the use of memory devices integral with the ink reservoirs which store ink consumption data (for use by a coupled ink jet printer). European patent EP 0 720 916, entitled "Ink Supply Identification System for a Printer" describes the use of an ink supply having an integral EEPROM which is utilized to store data regarding the identity of the ink supply and its fill level.

The prior art further teaches the use of consumable parts with integral memory for use in electrophotographic printers. In U.S. Pat. No. 5,021,828 to Yamaguchi et al., entitled "Copying Apparatus having a Consumable Part", a toner cartridge is disclosed which includes a memory for storing data regarding to the state of consumption of toner in the cartridge. U.S. Pat. Nos. 4,961,088 to Gilliland et al.; 4,803,521 to Honda; 5,184,181 to Kurando et al.; and 5,272,503 to LeSueur et al. all describe various replaceable toner cartridges for use in electrophotographic printers. Each cartridge incorporates a memory device for storing parameter data regarding the cartridge.

Ink jet and laser printers have, in recent years, become more sophisticated in their operational and control functionalities. For instance, many such printers exhibit resolutions at levels of 600 dots per inch (dpi), double the previous printer generation resolution of 300 dpi. At such higher resolutions, misadjustments which were not visible at lower resolution levels become highly visible. Further, such printers are now being applied to generation of grey-scale images on media, requiring precise density and tonal control of the deposited ink/toner.

Thus, while it has been known that changes in functionality of various elements of a printer interact to affect print quality, many of those interactions could be ignored in the lower resolution printers. However, with performance improvements of new printer designs, such interactions must now be taken into account and compensated to assure high quality print documents.

Accordingly, it is an object of this invention to provide a print apparatus with an improved capability for adjustment of printer control functions.

It is another object of this invention to provide an improved printer control system which is able to update control parameters that are dependent upon current printer performance parameters contained on plural consumable parts.

It is yet another object of this invention to provide an improved ink jet printer which incorporates real time print control functions that are responsive to parameters read from plural consumable parts.

SUMMARY OF THE INVENTION

A printer includes a replaceable cartridge for housing a supply of consumable marking media. The cartridge includes a cartridge memory for recording printer-related parameters, including marking media parameters. A replaceable printing device, such as an ink jet head, includes a printhead memory for recording printing device-related parameters. A processor is coupled to the cartridge memory, the printhead memory and is responsive to parameters read from both memories to derive printer function control values that are dependent upon one or more marking media parameters from the cartridge memory and one or more parameters from the printhead memory. The processor is thus able (in the case of an ink jet printer) to determine a current ink supply value from a cumulative usage value stored on the cartridge memory and a drop volume parameter stored on the printhead memory. Further, a drop volume parameter stored on the printhead memory can be adjusted to accommodate a media type sensed by a media sensor.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1*a* is a perspective view of an ink jet printer (with cover removed), which incorporates the invention.

FIG. 1*b* is a block diagram of components of the ink jet printer of FIG. 1*a*.

FIG. 2 is a frontal view of an ink-containing cartridge usable in the ink jet printer shown in FIG. 1.

FIG. 3 is a side view of the ink cartridge of FIG. 2.

FIG. 4 is a schematic sectional view of the ink cartridge of a FIG. 2.

FIG. 4*a* is an expanded view of FIG. 4, showing details of a cartridge memory installed on the ink cartridge.

FIG. 5 is a perspective view of an ink jet printhead employed with the invention hereof.

FIG. 6 is a schematic diagram indicating certain data stored in the cartridge memory contained on the ink cartridge of FIG. 2 and the printhead memory stored on the printhead of FIG. 5, and illustrating the usage of such data in deciding printer control values.

FIG. 7 is a schematic of a display used in the system of FIG. 1, illustrating a "gas gauge" to indicate the ink supply level in the ink cartridge of FIG. 2.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 1*a* illustrates a perspective view of an ink jet printer 1 incorporating the invention. A tray 2 holds a supply of

input paper or other print media. When a printing operation is initiated, a sheet of paper is fed into printer 1 and is then brought around in a U direction towards an output tray 3. The sheet is stopped in a print zone 4 and a scanning carriage 5, containing plural, removable color printheads 6, is scanned across the sheet for printing a swath of ink thereon. The process repeats until the entire sheet has been printed, at which point, it is ejected onto output tray 3.

Printheads 6 are, respectively, fluidically coupled to four removable ink cartridges 7 holding Cyan, Magenta, Yellow and Black inks. Since black ink tends to be depleted most rapidly, the black ink cartridge has a larger capacity than the other cartridges. As will be understood from the description which follows, each printhead and ink cartridge is provided with an integral memory device which stores data that is used by printer 1 to control its printing operations.

FIG. 1*b* illustrates a block diagram of elements of the ink jet printer of FIG. 1*a*. Ink jet printer 1 includes a pluggable printhead 12 which includes a print element 14 and an integrally mounted printhead memory 16. Printhead 12 is pluggably removable from printer 1 via interconnects 18. An ink cartridge 20 is also pluggably removable from printer 1 via electrical interconnect 22 and fluidic interconnect 24. Ink cartridge 20 includes an ink reservoir 26 and an integral cartridge memory 28. The contents of memories 16 and 28 will be considered in detail below and, as will be understood, are instrumental in enabling real time control of ink jet printer 1 to produce high quality printed media.

A media detector 30 is positioned to scan an incoming media sheet 32 and determine from characteristics thereof, the specific type of media sheet which is being presented to printhead 12 for printing. Media sheet 32 may carry indicia that is only visible to media detector 30 (e.g., via an infra-red scan) or other indicia indicative of the media type.

Ink cartridge 20, printhead 12 and media detector 30 are interconnected to a microprocessor 34 which includes both electronics and firmware for the control of the various printer sub-assemblies. A print control procedure 35, which may be incorporated in the printer driver, causes the reading of data from cartridge memory 28 and printhead memory 16 and adjusts printer control parameters in accordance with parameter re-calculations based upon the data accessed from both memories.

A host processor 36 is connected to microprocessor 34 and includes a central processing unit (CPU) 38 and a software printer driver 40. A monitor 41 is connected to host processor 36 and is used to display various messages that are indicative of the state of ink jet printer 1.

FIG. 2 illustrates a frontal view of ink cartridge 20 and FIG. 3, a side view thereof. Ink cartridge 20 is pluggable into a receptacle (not shown) in ink jet printer 1 and includes both a fluidic interconnection and an electrical interconnection, both of which are accessible through bottom surface 42. FIG. 4 shows a section of ink cartridge 20 and illustrates the positioning of ink reservoir 26, a fluidic connector 44 and an electrical connector 46. Electrical connector 46 enables interconnection to a cartridge memory chip 20.

An expanded view of connector 46 and memory chip 20 are shown in FIG. 4*a*, with connector 46 making contact to a mating connector in the receptacle within ink jet printer 1 when ink jet cartridge 20 is pluggably inserted thereinto.

FIG. 5 is a perspective view of printhead 12 and illustrates the placement of printhead memory 16 thereon. A plurality of contacts 48 enable pluggable interconnection to printhead memory 16 as well as various electrical elements within printhead 12. Printhead 12 is a known, thermally-actuated ink jet printhead, with a print element (including an orifice plate) positioned at surface 14. Behind each orifice is an ink chamber with a heater resistor. A thermal sense resistor is positioned on the printhead and detects the temperature of the semiconductor substrate on which the heater resistors are positioned. A fluidic interconnect 50 connects ink cartridge 12, via ink flow path 24 (see FIG. 1), to ink reservoir 26 in ink cartridge 20. When printhead 12 is plugged into a receptacle (not shown) within ink jet printer 1, contacts 48 make electrical connection to a mating connector in the printer and fluidic interconnect 50 automatically mates to ink flow path 24 to enable a flow of ink thereto.

As indicated above, cartridge memory 28 and printhead memory 16 enable microprocessor 34 to calculate control values which enable printer 1 to maintain high quality print media output. Data from media detector 30 is also employed for certain aspects of print media quality enhancement. To accomplish control of printer parameters, each of memories 16 and 28 includes both factory-written data and printer-recorded data. While not complete, the following is a list of data values stored within the aforesaid memories:

Cartridge memory 16
- Factory-written data:
- Product tag
- Supply size
- Color map coefficients
- Ink colorimetry
- Color code
- Dry time coefficient
- Printer driver revision number
- Printer driver revision parameters
- Re-order part number
- Manufacture day
- Manufacture year
- Freshness date
- Ink shelf life
- Serial number
- Print mode coefficients
- Outgas rate data for ink
- Printer written data:
- Coarse count
- Fine count
- First insertion date
- Last usage date
- In-use time

Printhead memory 16
- Factory recorded data:
- Product tag
- Drop volume measurement
- Drop volume coefficients
- Manufacture year
- Manufacture day
- Freshness date
- Temperature sense resistor calibration data
- Printhead alignment coefficients
- Firing energy parameters
- Print mode coefficients
- Re-order part number
- Driver version number
- Printer-recorded data:

Number of drops fired
First insertion date
Last usage date
In-use time
Number of pages printed.

As will be hereafter understood, print control procedure **35** makes use of the above-indicated parameters stored in memories **16** and **28** to control the operation and print quality of media output from ink jet printer **1**. In a number of instances, data from both memories **16** and **28** are utilized to arrive at an improved control parameter. Further, the ability to periodically replace memories **16** and **28**, as their host carriers (e.g., printhead **12** or ink cartridge **20**) are replaced, enables the manufacturer to provide updated parameters, on a continuing basis, to customers who already have installed printers.

Turning to FIG. **6**, subprocedures incorporated into print control procedure **35** will be described which utilize data from both printhead memory **16** and cartridge memory **28** and, in some cases, an input from media sensor **30**. Before describing the subprocedures, it is worthwhile to consider certain details of the data stored in printhead memory **16** and cartridge memory **28**.

A fine count value **52** stored in cartridge memory **28** is an 8-bit (for example) re-writable value, with each bit corresponding to 1/256 of 12.5% of the total supply volume of ink cartridge **20**. To calculate when to "flip" a fine count bit value, print control procedure **35** reads both a drop volume parameter **54** (encoded on printhead memory **16**) and an ink supply volume value **56** (encoded on cartridge memory **28**). Print control procedure **35** then calculates how many drops are required too cause one fine count bit flip (i.e., an amount equal to 1/256 of 12.5% of the total supply volume). Then. by counting input signals fed to the heater resistors (as indicative of the cumulative number of emitted ink drops), print control procedure **35** knows when to increment the value in fine count value **52**.

When ink cartridge **20** is first inserted, print control procedure **35** reads the manufacture day/year data **58** to determine the age of ink cartridge **20**. Thereafter, the value of fine count entry **52** is adjusted to take into account evaporation assumptions.

A coarse count value **60** in cartridge memory **28** is incremented each time 12.5% of the ink in ink cartridge **20** is consumed. Coarse count value **60** is incremented each time fine count value **52** "rolls over". As will be hereafter understood, fine count value **52** and coarse count value **60** are both utilized to determine an amount of remaining ink in ink cartridge **20**.

As indicated in FIG. **6**, a drop usage calculation subprocedure **70** employs a number of values stored on both cartridge memory **28** and printhead memory **16** to calculate an amount of ink remaining in ink cartridge **20**. Thus, drop usage calculation subprocedure **70** reads drop volume parameter **54** from printhead memory **16** and ink supply size parameter **56** from ink cartridge memory **28**. Further, inputs from thermal sense resistors **76** (associated with print element **14** in FIG. **1**) are also input to drop usage calculation subprocedure **70**. From the drop volume parameter and thermal sense resistor inputs, the total volume of drops emitted are calculated and, using supply size parameter **56**, subprocedure **70** calculates the remaining amount of ink available in cartridge **28**. Upon arriving at such a calculated value, fine count value **52** is incremented to reflect the current ink usage state and, if a "roll-over" of the count is sensed, coarse count value **60** is also incremented. These calculations occur as printing takes place, with fine count value **52** and coarse count value **60** being incremented to reflect the volume of ink ejected by printhead **12**. As drop usage calculation subprocedure **70** arrives at new values for fine count value **52** and coarse count value **60**, such values are accordingly rewritten into cartridge memory **28** via data line **74**.

Because ink supply cartridge sizes will vary, both drop volume parameter **54** and initial supply size parameter **56** are used in the calculation.

A drop volume parameter update subprocedure **75** is periodically run to account for changes in drop volume which occur as printhead **12** ages. Drop volume parameter update subprocedure **74** initially accesses drop volume parameter **54** from printhead memory **16**. It then employs cumulative usage data to estimate the state of the printhead. That cumulative usage value is calculated by use of fine count value **52**, coarse count value **60** from a current ink cartridge **20** and previous fine and coarse count values from now-replaced ink cartridges. That data is accumulated on printhead memory **16** in the form of a cumulative "number of drops fired" value **76**. An algorithm for re-calculation of drop volume uses the following expressions:

$$Vcalc = Vmeas + \Delta Vtrans + \Delta Vtime + \Delta V\#drops + \Delta V(T) + \Delta V(f)$$

$$\Delta Vtime = k1t + k2t^2 + \ldots$$

$$\Delta V\#drops = c1N + c2N^2 + \ldots$$

$$\Delta V(T) = b1T + b2T^2 + \ldots$$

$$\Delta V(f) = d1f + d2f^2 + \ldots$$

where:

Vcalc=calculated drop volume

Vmeas=drop volume measured in the factory.

ΔVtrans=transient drop volume change (from surface wetting or burn-in).

ΔVtime=effect of time (long term) on drop volume

k1, k2, . . . =constants

t=time elapsed since printhead was manufactured

Note: the constants are characterized and encoded at the printhead factory; the time t is calculated by the printer by comparing the computer clock to the date code on the printhead.

ΔV#drops=effect of firing on drop volume (long term—build up on resistor)

c1, c2, . . . =constants

N=number of drops fired since printhead was manufactured

ΔV(T)=effect of temperature

b1, b2, . . . =constants

T=printhead temperature. It is calculated from a formula that relates the temperature to the TSR (thermal sense resistor) output; the TSR is monitored by the system to infer head temperature.

ΔV(f)=Effect of firing frequency

d1, d2, . . . =constants

Note: Vtrans, k1, k2, d1, d2, c1, c2, b1, b2 are recorded at the factory; t is recorded on the printhead memory chip by the printer (by comparing a computer clock to the date code recorded on the ink cartridge memory); and N is recorded on the cartridge memory chip by the printer.

As the usage of printhead **12** increases, drop volume parameter update subprocedure **74** alters the drop volume parameter to track changes in the drop volume (e.g., as a result of ink build-up in the ink chambers and other factors). That drop volume parameter may then be rewritten to printhead memory **16** via data line **80**.

In order to provide the user with an indication of remaining ink in ink cartridge **20**, drop usage calculations subpro-

cedure **70** provides an output value to host processor **36** which implements a display procedure to cause monitor **40** to exhibit a "gas gauge" which is shown on monitor **41** in FIG. 7. Monitor **41** includes a gas gauge representation **73** in the lower left corner thereof. As the remaining ink quantity in ink cartridge **20** reduces, the indication of gas gauge **73** is altered accordingly.

A further subprocedure is periodically run each time a new media type is sensed by media sensor **30**. As indicated above, media sensor **30** is enabled to detect a specific media type by invisible or visible indicia imprinted on the media and to provide a media type value to a dot density calculation subprocedure **82**. In response, dot density calculation subprocedure **82** reads drop volume parameter **54** from printhead memory **16** and ink colorimetry parameter **84** from ink cartridge memory **28**. Utilizing those two parameters, dot density calculation subprocedure **82** then calculates adjustments required for changes in dot density to achieve a correct hue and intensity on the sensed media type.

It should be understood that the foregoing description is only illustrative of the invention. Various alternatives and modifications can be devised by those skilled in the art without departing from the invention. While the above invention has been described in the context of an ink jet printer, those skilled in the art will realize that it is equally applicable to other printer/copier arrangements which employ replaceable units and wherein control procedures are dependent upon parameters read from multiple such replaceable units. Accordingly, the present invention is intended to embrace all such alternatives, modifications and variances which fall within the scope of the appended claims.

I claim:

1. A printing system comprising:

replaceable cartridge means for housing a supply of consumable marking media and including cartridge memory means for recording printer-related parameters, including marking media parameters;

replaceable print means for producing marks on a print media and including printhead memory means mounted thereon for recording print means-related parameters;

processor means coupled to said cartridge memory means and said printhead memory means and responsive to parameters read from both said cartridge memory means and said printhead memory means for deriving a printer function control value that is dependent upon at least a marking media parameter from said cartridge memory means and a print means-related parameter from said printhead memory means.

2. The printing system as recited in claim **1**, wherein said replaceable cartridge means is an ink reservoir cartridge that is pluggably insertable into said printing system and said cartridge memory means forms an integral part of said cartridge and makes electrical connection to said printing system upon insertion of said cartridge.

3. The printing system as recited in claim **2**, wherein said printing system control function value is a number of ink drops that are fired per count of an ink volume counting means.

4. The printing system as recited in claim **2**, wherein said replaceable print means is an ink jet printhead that is pluggably insertable into said printing system and said printhead memory means forms an integral part of said ink jet printhead and makes electrical connection to said printing system upon insertion of said ink jet print head.

5. The printing system as recited in claim **4**, further comprising:

sense means coupled to said ink jet printhead for producing signals indicative of mark production by said ink jet printhead, said processor means further employing data derived from said signals to arrive at said printing system control function value.

6. The printing system as recited in claim **5**, wherein a parameter relating to current ink volume received by said processor from said cartridge memory means, a parameter relating to drop volume received from said printhead memory means and said data derived from said sense means, are combined by said processor means to adjust said parameter relating to current ink volume.

7. The printing system as recited in claim **6**, wherein said processor means causes said parameter relating to current ink volume, that is adjusted, to be written back into said cartridge memory means.

8. The printing system as recited in claim **6**, further comprising:

display means coupled to said processor means; and

wherein said processor means is responsive to said value of current ink volume that is adjusted and a parameter from said cartridge memory means relating to cartridge supply ink volume, to provide a gauge indication on said display means which indicates an amount of ink remaining in said ink reservoir cartridge.

9. The printing system as recited in claim **4**, further comprising;

media sense means for providing to said processor means a media type signal that is dependent upon a type of media sheet present in said printing system; and

wherein said media type signal and a parameter read from said cartridge memory means are employed by said processor means to provide a control signal for adjusting dot density produced by said printing system.

10. A method for controlling operation of a printing system, wherein the printing system includes (i) a replaceable cartridge for housing a supply of consumable marking media, said cartridge further including a cartridge memory mounted thereon for recording printing system-related parameters, including marking media parameters and (ii) replaceable print means for producing marks on a print media and further including a print memory mounted thereon for recording print means-related parameters, the method comprising the steps of:

reading parameters stored on both said cartridge memory and said print memory; and

deriving a printing system function control value that is dependent upon at least a marking media parameter read from said cartridge memory and a print means-related parameter read said print memory means.

11. The method as recited in claim **10**, further comprising the steps of:

deriving signals from said print means indicative of mark production thereby; and

employing data derived from said signals to arrive at said printing system control function value.

12. The method as recited in claim **10**, further comprising the steps of:

sensing a media type signal that is dependent upon a type of media sheet present in said printing system; and

combining said media type signal and a parameter relating to a marking media characteristic in said cartridge, received from said cartridge memory, to provide a control signal for adjusting dot density produced by said printing system.

13. The method as recited in claim **10**, further comprising the steps of:

adjusting a parameter relating to current marking media volume in accord with said control signal; and

writing said parameter that is adjusted back into said cartridge memory.

14. The method as recited in claim **10**, further comprising the steps of:

displaying a gauge indication which indicates an amount of marking media remaining in said cartridge, said amount determined from said value of current marking media that is adjusted and a parameter from said cartridge memory relating to cartridge marking media ink volume.

15. A replaceable ink cartridge for an ink jet printing system, the printing system including a replaceable printhead for producing marks on a print media, the replaceable printhead having a printhead memory element mounted thereon for recording print means-related parameters, the printing system including a processor means that is coupled to the printhead memory element when the replaceable printhead is releasably coupled to the printing system, the replaceable ink cartridge comprising:

an ink reservoir containing an ink supply;

a discharge port in fluid communication with the ink reservoir, the discharge port establishing fluid communication with a fluid inlet in the ink station when the ink cartridge is releasably mounted to the receptacle; and

a cartridge memory element mounted thereon and having cartridge-related parameters stored therein, the cartridge memory element electrically coupled with the processor means so that the processor means has access to the cartridge-related parameters when the ink cartridge is installed in the receptacle;

wherein, in order to carry out a printing operation where ink is transferred from the ink reservoir through the discharge port to the printhead, certain cartridge-related parameters stored in the cartridge memory element are stored and/or modified by signals from the processor means, and or transmitted from the ink cartridge to the processor means so that the processor means derives a printing system function control value that is dependent upon at least both a cartridge-related parameter and a printhead-related parameter when the replaceable print means and the replaceable ink cartridge are releasably installed in the ink jet printing system.

16. The replaceable ink cartridge of claim **15**, wherein the cartridge-related parameters include factory parameters that are recorded at the time the ink cartridge is manufactured.

17. The replaceable ink cartridge of claim **16**, wherein the cartridge factory parameters include the volume of the ink supply.

18. The replaceable ink cartridge of claim **16**, wherein the printhead-related parameters include factory parameters that are recorded at the time the replaceable printhead is manufactured.

19. The replaceable ink cartridge of claim **18**, wherein the factory parameters include a printhead drop volume.

20. A replaceable ink cartridge for an ink jet printing system, the printing system including a plurality of printheads of different colors for ejecting droplets of ink on media, each printhead including a printhead memory element mounted thereon and having printhead factory parameters stored therein, the printing system having a processor means for controlling printing system function, the processor means coupling with the printhead memory element so that the processor means has access to the printhead factory parameters, the printing system including an ink station for supplying ink to the printhead, the ink station including a plurality of receptacles corresponding to the plurality of printheads, the replaceable ink cartridge comprising:

a cartridge body having an ink reservoir therein, the cartridge body adapted to be releasably mounted to one of the plurality of receptacles in said ink jet printing system;

a discharge port in fluid communication with the ink reservoir, the discharge port establishing fluid communication with a fluid inlet in one of the plurality of receptacles when the cartridge body is releasably mounted to one of the plurality of receptacles to thereby enable ink to flow out of the discharge port and to an associated printhead when the cartridge body is releasably mounted to one of the plurality of receptacles; and

an ink cartridge memory element mounted thereon and adapted to electrically couple to the processor means when the cartridge body is releasably mounted to one of the plurality of receptacles, the ink cartridge memory element thereby providing ink cartridge factory parameters to the processor means; and

wherein, in order to carry out a printing operation where ink is transferred from the ink reservoir through the discharge port and to the printhead, certain factory-inserted parameters stored in the ink cartridge memory element are transmitted from the ink cartridge memory element to the processor means so that the processor means combines at least one ink cartridge factory-inserted parameter and at least one printhead factory-inserted parameter, to derive a usage control parameter for the printhead.

21. The replaceable ink supply of claim **20**, wherein the ink reservoir has a deliverable volume of ink and wherein the at least one ink cartridge factory parameter includes a value corresponding to the deliverable volume of ink.

22. The replaceable ink supply of claim **20**, wherein the at least one printhead factory parameter includes a value corresponding to the drop volume of the printhead.

23. The replaceable ink supply of claim **20**, wherein the ink reservoir has a usage life, and the processor means periodically calculates the usage control parameter during a usage life of the ink reservoir to provide an updated usage value, the processor means periodically writing the updated usage value to the ink cartridge memory element.

24. The replaceable ink supply of claim **23**, wherein the processor means reads the usage control parameter from the ink cartridge memory element, the processor means combines at least one ink cartridge factory parameter, at least one printhead factory parameter, and the usage control parameter to calculate the updated usage control parameter.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 5,812,156

DATED : September 22, 1998

INVENTOR(S) : Bullock et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

At Column 8, beginning on line 39 and continuing through line 41, delete "said cartridge further including a cartridge memory mounted thereon for recording printing system-related parameters, including marking media parameters"

At Column 8, beginning on line 43 and continuing on line 44, delete "and further including a print memory mounted thereon for recording print means-related parameters";

At Column 8, line 46, before "reading", insert

--utilizing a cartridge memory which stores printed system related parameterr and is mounted on said replaceable cartridge;

and further utilizing a print memory which stores print means-related parameters and is mounted on said replaceable printer means ;--.

Signed and Sealed this

Fifth Day of January, 1999

Attest:

Attesting Officer

Acting Commissioner of Patents and Trademarks

US005513563A

United States Patent [19]

Berson

[11] **Patent Number:** **5,513,563**

[45] **Date of Patent:** **May 7, 1996**

[54] **INDICIA SECURITY VIA VARIABLE DOT SIZE**

[75] Inventor: **William Berson**, Weston, Conn.

[73] Assignee: **Pitney Bowes Inc.**, Stamford, Conn.

[21] Appl. No.: **339,049**

[22] Filed: **Nov. 14, 1994**

[51] **Int. Cl.**^{6} **B41J 2/01**

[52] **U.S. Cl.** **101/91**; 400/124.30; 347/15; 382/299; 364/408; 235/101

[58] **Field of Search** 101/71, 91; 400/103, 400/104, 124.02, 124.04, 124.30; 235/101; 347/14, 15; 364/408, 464.01, 464.02, 918.52, 930–930.7; 382/298, 299, 300, 301; 395/107, 108, 109, 110

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Primary Examiner—David A. Wiecking
Attorney, Agent, or Firm—Ronald Reichman; Melvin J. Scolnick

[57] **ABSTRACT**

A system is disclosed that makes it more difficult to print fraudulent indicia. Security is achieved by varying the dot size of pixels in the printed image according to a predetermined arrangement.

5 Claims, 3 Drawing Sheets

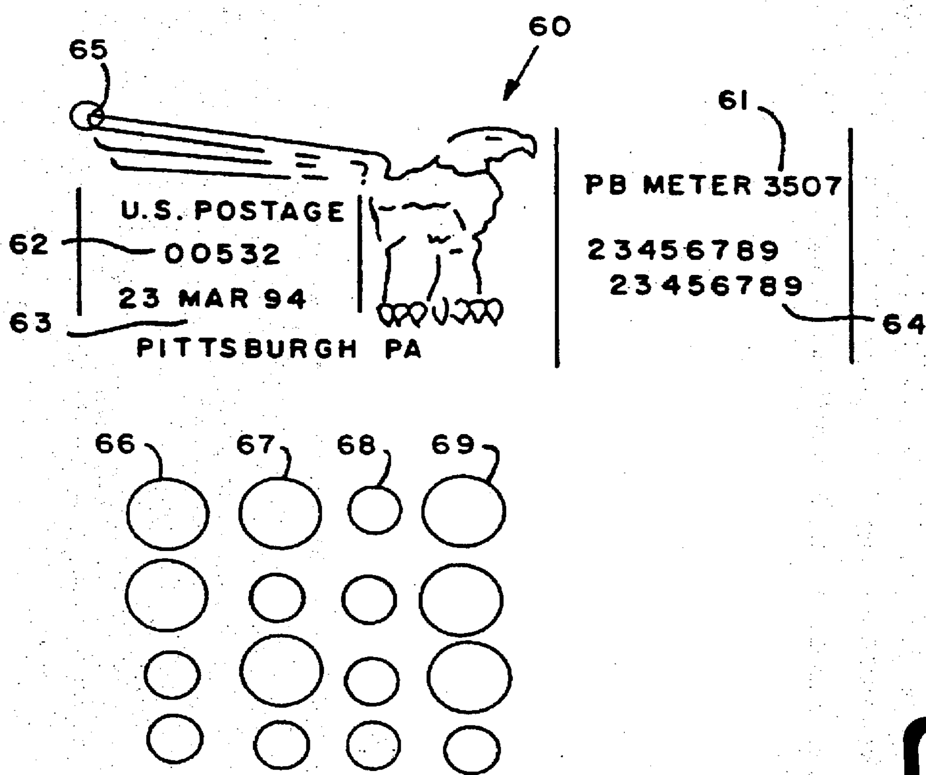
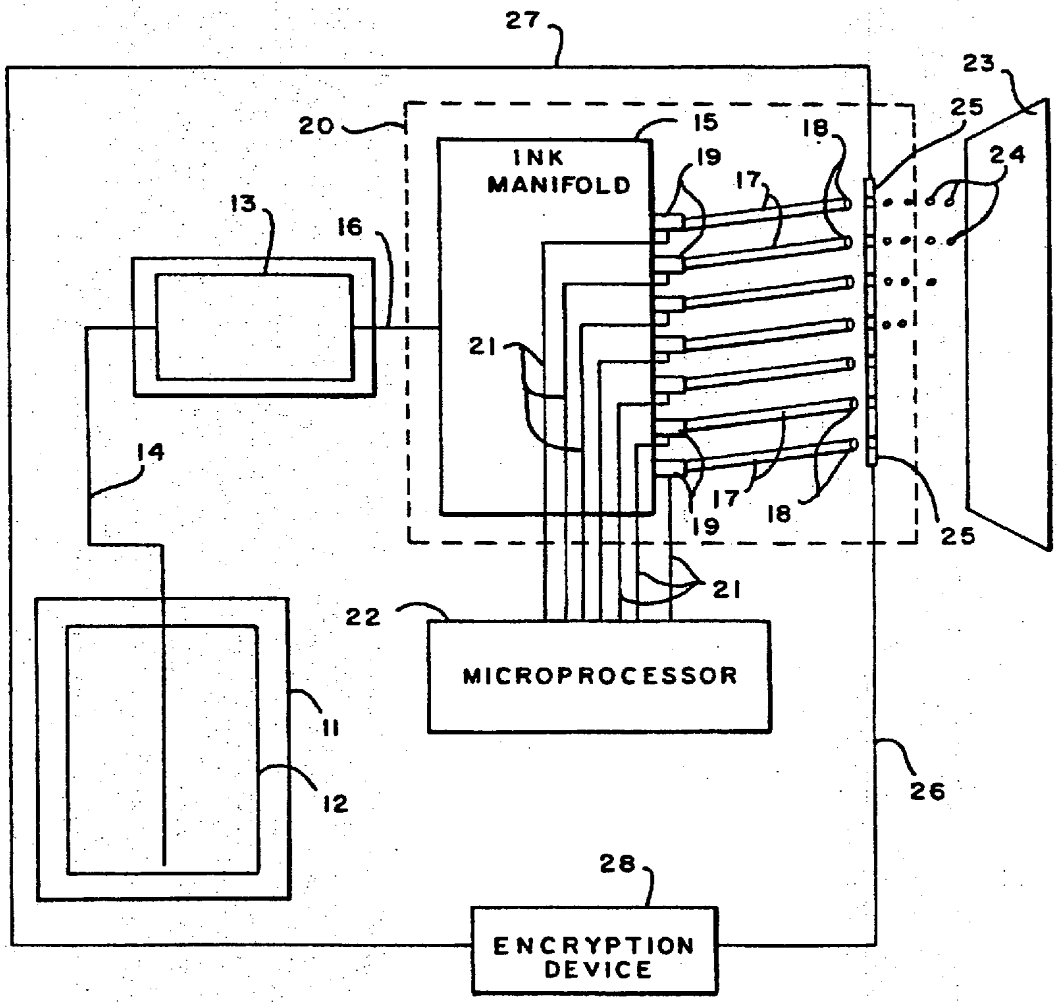


FIG. I


27
23
20
15
25
18
INK
MANIFOLD
19
24
17
13
16
21
14
17
18
19
25
21
22
MICROPROCESSOR
11
12
26
28
ENCRYPTION
DEVICE

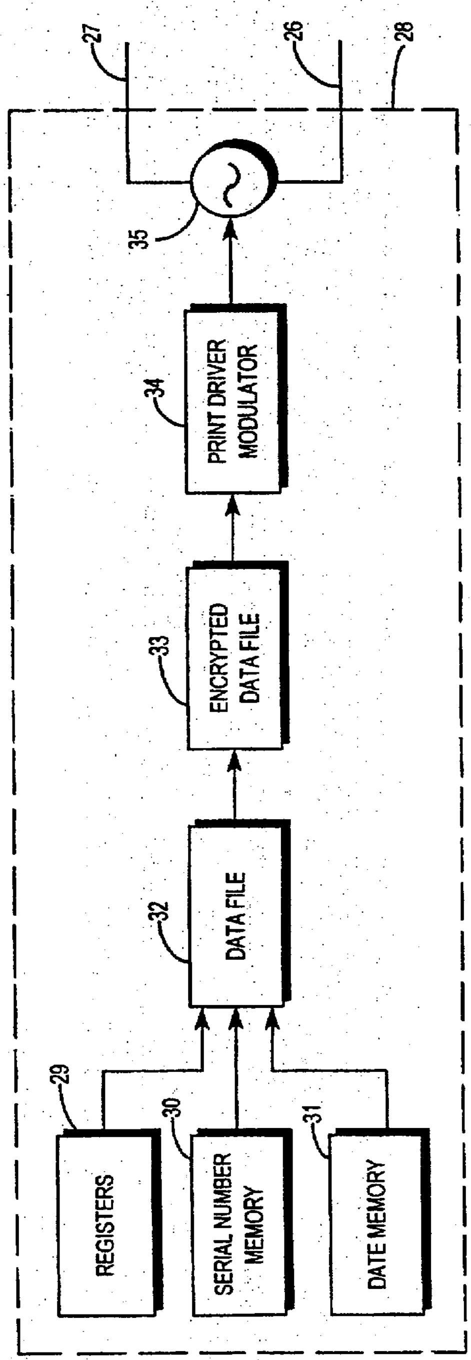

27
26
28
35
PRINT DRIVER MODULATOR
34
ENCRYPTED DATA FILE
33
DATA FILE
32
29
30
31
REGISTERS
SERIAL NUMBER MEMORY
DATE MEMORY

FIG. 2

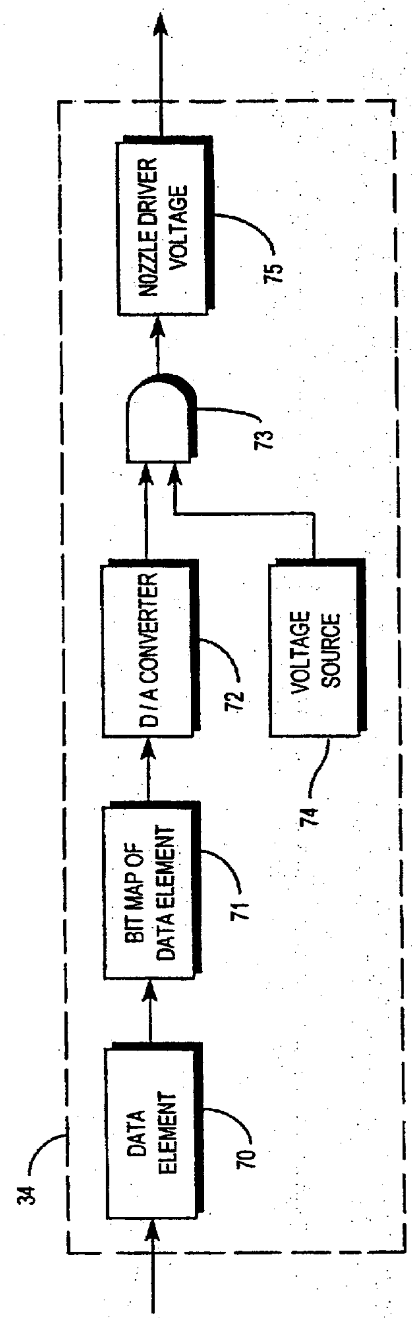

NOZZLE DRIVER VOLTAGE
75
73
D / A CONVERTER
72
VOLTAGE SOURCE
74
BIT MAP OF DATA ELEMENT
71
DATA ELEMENT
70
34

FIG. 3

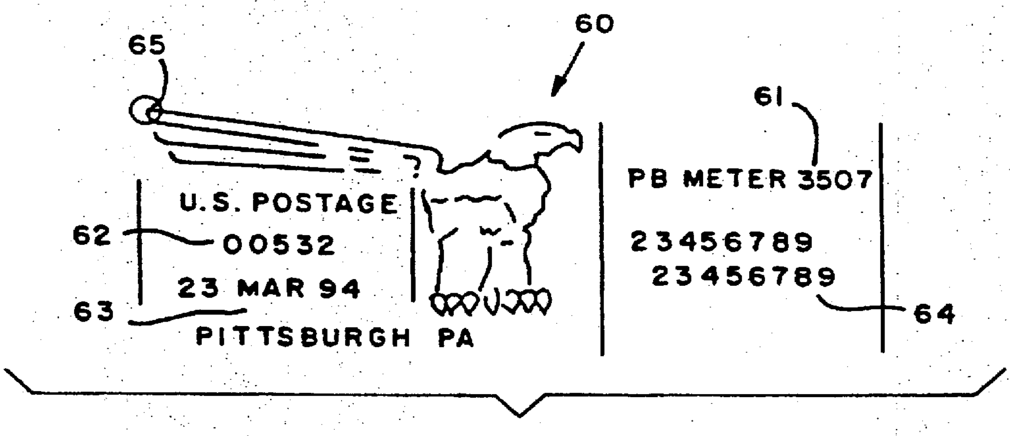

60
65
61
PB METER 3507
U.S. POSTAGE
62
00532
23456789
23456789
23 MAR 94
63
64
PITTSBURGH PA

FIG. 4

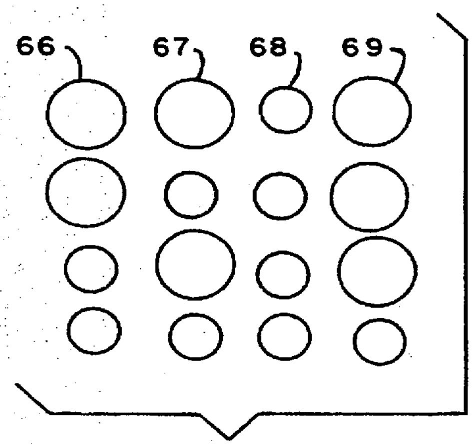

66
67
68
69

FIG. 5

INDICIA SECURITY VIA VARIABLE DOT SIZE

FIELD OF THE INVENTION

This invention pertains to printers which print characters composed of dots and more particularly to printers that are controlled electronically to print characters of variable dot size.

DESCRIPTION OF THE PRIOR ART

Since the issuance of U.S. Pat. No. 1,530,852 to Arthur H. Pitney, Mar. 24, 1925, the postage meter has had a steady evolution. Each meter had a printer included therein on a one-to-one basis, i.e. one metering device and one printing device incorporated into a unit. In postage meters, the need for security is absolute. Such security is applied in prior postage meters both to the printing portion of the meter and the accounting portion. The reason for the need of absolute security is because a postage meter is printing value, and unless security measures are taken, one would be able to print unauthorized postage, i.e. postage for which no payment is made, thereby defrauding the postal service.

Printers that print characters in the form of dots have been utilized in postage meters. The aforementioned printers form characters from a matrix of dots. Unlike the face character printing methods, the printing elements are organized in columns or rows which print dots. A character in a dot printer is formed sequentially by printing at one time either all the selected dots, respectively in a column or a row. Graphics are made possible by precisely positioning dots on a page.

Although postage meters have performed satisfactorily in the past, and continue to perform satisfactorily, with the advancement of technology it is becoming easier to print fraudulent indicia.

SUMMARY OF THE INVENTION

This invention overcomes the disadvantages of the prior art by providing a system that makes it more difficult to print fraudulent indicia. The apparatus of this invention provides a device for verifiable security in a postage meter or other device using dot matrix or bit-addressable printing. Security is achieved by varying the dot size of pixels in the printed image according to a predetermined arrangement. The dot size variation is used to encode the meter serial number, ascending and descending funds registers, mail piece identifier date, time and origin of mail piece and other data which may be used for indicia variation and to prevent fraud.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a drawing of the apparatus of this invention;

FIG. 2 is a block drawing of encryption device 28 of FIG. 1 in greater detail;

FIG. 3 is a block drawing of driver modulator 34 of FIG. 2 in greater detail;

FIG. 4 is a drawing of an indicia in which print head 20 has imprinted the postal information thereon; and

FIG. 5. is a drawing of an expanded view of portion 65 of the indicia shown in FIG. 4.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings in detail, and more particularly to FIG. 1, the reference character **11** represents an ink cartridge containing ink **12** therein. Cartridge **11** is connected to an ink filter **13** by means of conduit **14**. Ink filter **13** is connected to an ink manifold **15** by means of conduit **16**. A plurality of generally vertically spaced capillary tubes **17** are confluent with the manifold **15** and have orifices or nozzles **18** at one end thereof and transducers or piezoelectric devices **19** at the other end thereof. A deflection plate or drop array **25** is placed in front of apertures **18**. The other end of array **25** is connected to microcomputer **22**. The ink manifold **15**, capillary tubes **17**, nozzles **18**, piezoelectric devices **19** and drop array **25**, define a print head **20**. A plurality of electrical leads **21** are connected to the piezoelectric devices **19** there being one lead for each piezoelectric device **19**. The electrical leads **21** are connected to a microcomputer **22**. The microcomputer **22** will control piezoelectric devices **19** to propel drops of ink **24** through capillary tubes **17**, through nozzles **18** onto printing medium or writing surface **23**. Thus, ink drops **24** can be released from nozzles **18** on demand. Ejection is by means of shock waves from piezoelectric devices **19** which momentarily increases the pressure of nozzles **18**.

Ink drops **24** are of uniform size and spacing, both being a function of the pressure at nozzles **18**, the viscosity and surface tension of the ink of the ink, the diameter of nozzles **18**, the surface energy of the nozzle material, and the vibration frequency of nozzles **18**. Each drop of ink **24** may be given a precise electrostatic charge by drop array **25**. The size of ink drops **24** and consequently the dot size that appears on writing surface **23** may be varied by varying the driving voltage of drop array **25**. One end of lead **26** is connected o to drop array **25** and the other end of lead **26** is connected to encryption device **28**. One end of lead **27** is connected to drop array **25** and the other end of lead **27** is connected to encryption device **28**. The stream of controlled varying size ink droplets **24** will form character or graphics on writing surface **23**.

FIG. 2 is a drawing that shows encryption device **28** of FIG. 1 in greater detail. The postage used by a particular postal meter and the postage remaining to be used for a particular postage meter will be contained in registers **29**. The serial number of a particular postage meter will be stored in serial number memory **30** and the date that an indicia is affixed to a particular mail piece will be stored in date memory **31**. The output of registers **29**, serial number **30** and date memory **31** are individually coupled to the input of data file **32**. Data file **32** stores its inputted data and outputs the stored data to the input of encrypted data file **33**. Data file **32** encrypts its inputted data and transmits the encrypted data to the input of print head driver voltage **34**. The output of driver **34** will be a sequence of voltages that represent a sequency of dots of varying diameters. The operation of driver **34** will be described in the description of FIG. 3. The output of driver **34** is coupled to the input of voltage source **35** and the output of voltage source **35** is coupled to array **25** by leads **26** and **27**.

FIG. 3 is a block drawing that shows driver **34** of FIG. 2 in greater detail. Driver **34** comprises: data element **70**; bit map of data element **71**, digital to analog converter **72**; and gate **73**; voltage source **74**; and nozzle driver voltage **75**. Data element **70** receives serially one byte at a time encrypted data from file **72**. Element **70** processes the aforementioned encrypted data by obtaining is a bit by bit

representation of the data. The aforementioned bit by bit representation of the data is inputted to map **71**, where it is temporarily stored. The output of map **71** is coupled to the input of D/C converter **72**. D/A converter **72** converts its digital inputs into an analog signal, which is coupled to one of the inputs of and gate **73**. The second input to gate **73** is the output of nozzle bias voltage source **74**. Gate **73** will be enabled when it receives an input from D/A converter **72** and voltage source **74**. The output of gate **73** will cause driver **75** to have an output voltage.

FIG. **4** is a drawing of an indicia in which print head **20** has imprinted the postal information thereon. The document **60** will have an indicia that contains a dollar amount **62**, the date the indicia was affixed to the mail piece **63**, and the postal meter serial number **61**. In addition, the document **60** will include a validation number **64**.

FIG. **5** is an expanded view of portion **65** of the indicia shown in FIG. **4**. The postal meter serial number **61** which was represented by the number **3507** in FIG. **4** would be represented in binary coded decimal in memory **30** (FIG. **2**) as 0011 0101 0000 0111 and may be encrypted by data file **33** as 1100 1010 0000 1110. The encrypted serial number 1100 1010 0000 1110 may be printed in portion **65** of the indicia shown in FIG. **4** with dots having different diameters. A large dot would represent a binary one and a small dot would represent a binary zero. The number 1100 is shown in column **66** and the number 1010 is shown in column **67**. The number 0000 is shown in column **68** and the number 1110 is shown in column **69**. The data that represents the serial number **61** was encrypted into a conventional mail piece by varying the dot size of the dots that comprise the indicia.

The above specification describes a new and improved apparatus for providing security to printed indicia by varying the dot size of the dots that comprise the indicia. It is realized that the above description may indicate to those skilled in the art additional ways in which the principals of this invention may be used without departing from the spirit. It is, therefore, intended that this invention be limited only by the scope of the appended claims.

What is claimed is:

1. A postal meter printer for printing alphanumeric characters and indicia on a plurality of mail pieces, said printer comprises:

means for printing a plurality of dots that represent the alphanumeric characters and indicia;

means for storing specific information about the postal meter and the plurality of mail pieces;

means coupled to said storing means for developing one or more codes that contain information about the postal meter and the plurality of mail pieces; and

means coupled to said developing means and said printing means for varying the dot size on specific printed regions of the plurality of mail pieces so that said one or more printed regions of the mail piece containing varying dot sizes will be coded in accordance with the code produced by said developing means without changing the identity of the alphanumeric characters and indicia.

2. The printer claimed in claim **1**, wherein said printing means comprises:

means for holding ink;

means coupled to said holding means for placing drops of ink that represent dots on the mail pieces.

3. The printer claimed in claim **2**, wherein said placing means comprises:

a tube in which ink flows coupled to said holding means;

means coupled to said tube for ejecting discrete quantities of ink from said tube;

means coupled to said ejecting means for supplying an electric charge to the quantities of ink to determine the size of the dots that represent alphanumeric characters and indicia.

4. The printer claimed in claim **3**, wherein said ejecting means is a piezoelectric device.

5. The printer claimed in claim **4**, wherein said supplying means is a deflection plate.

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